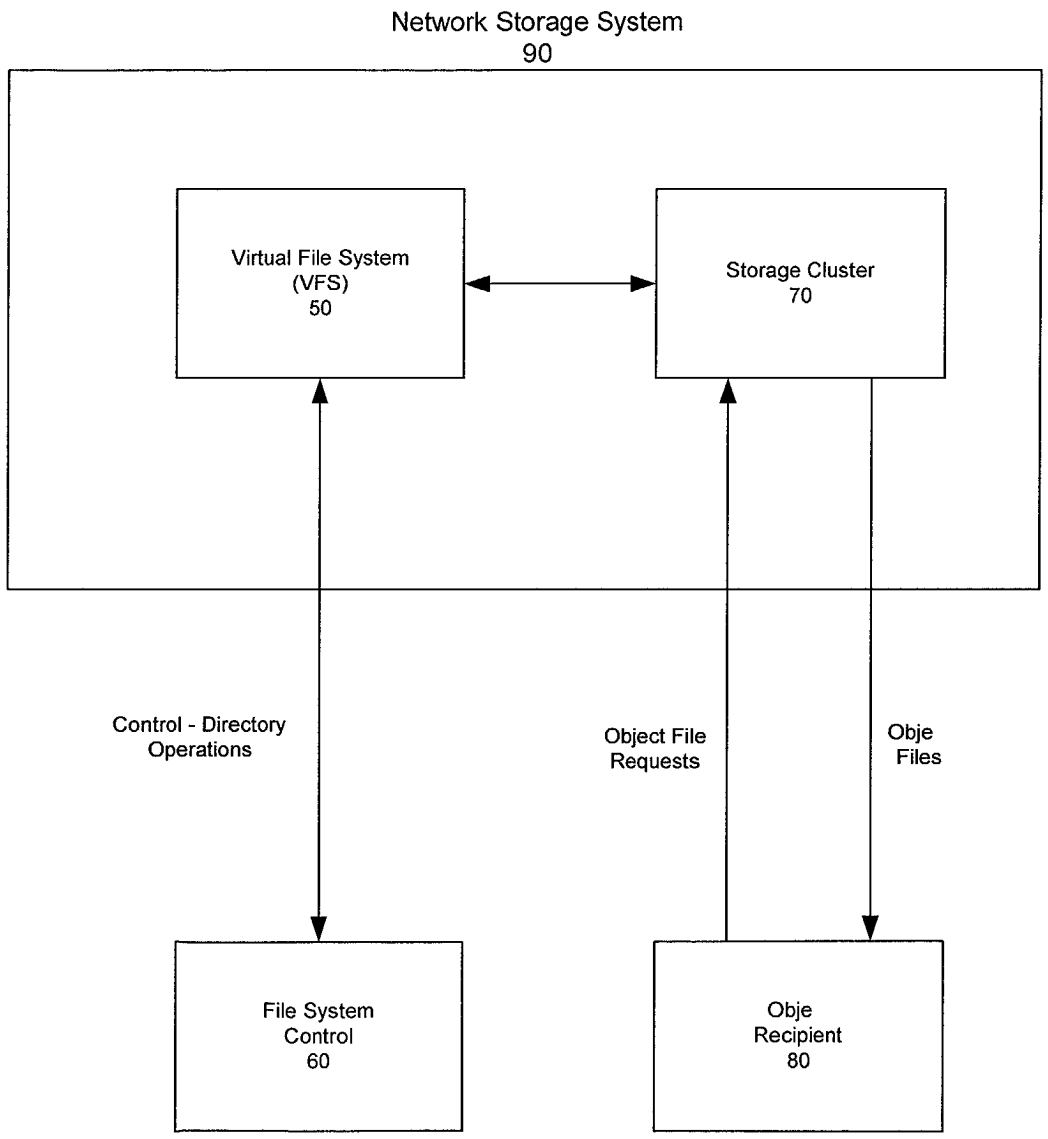

Network Storage System
90
Virtual File System
(VFS)
50
Storage Cluster
70
Control - Directory
Operations
Object File
Requests
Obje
Files
File System
Control
60
Obje
Recipient
80

Figure 1

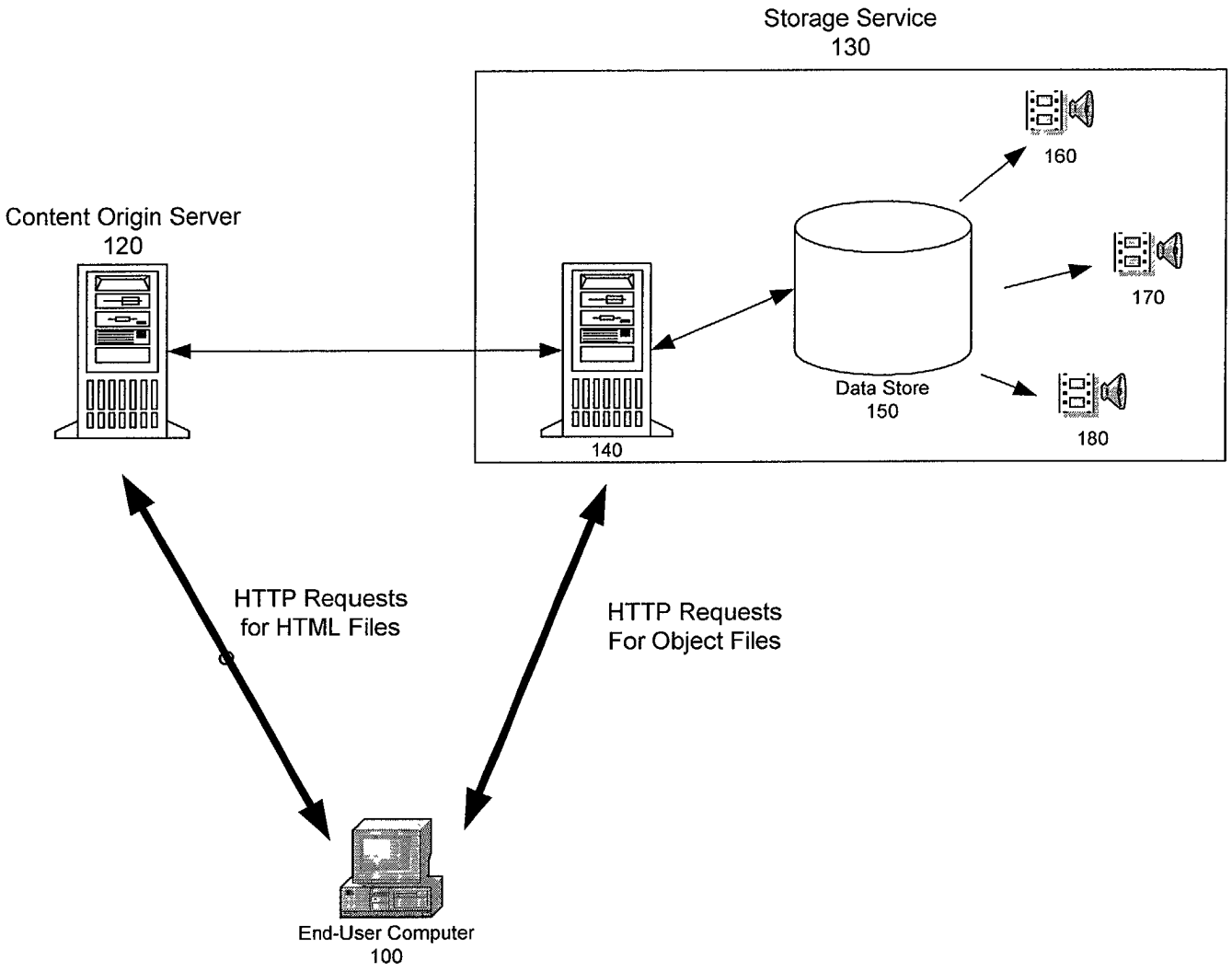

Storage Service
130
160
Content Origin Server
120
170
Data Store
150
140
180
HTTP Requests
for HTML Files
HTTP Requests
For Object Files
End-User Computer
100

Figure 2

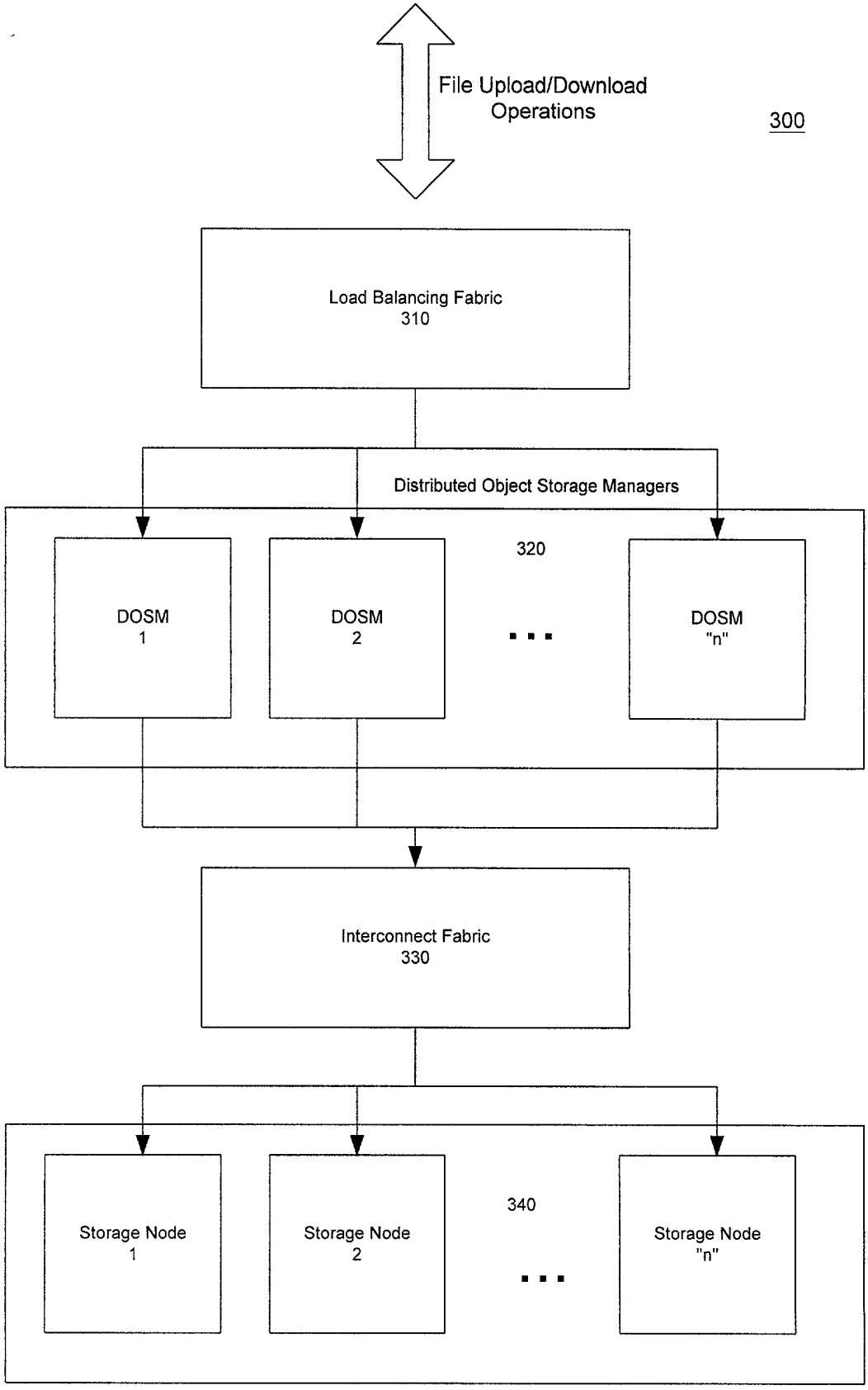

File Upload/Download Operations
300
Load Balancing Fabric
310
Distributed Object Storage Managers
DOSM
1
DOSM
2
320
DOSM
"n"
Interconnect Fabric
330
Storage Node
1
Storage Node
2
340
Storage Node
"n"
Intelligent Storage Nodes

Figure 3

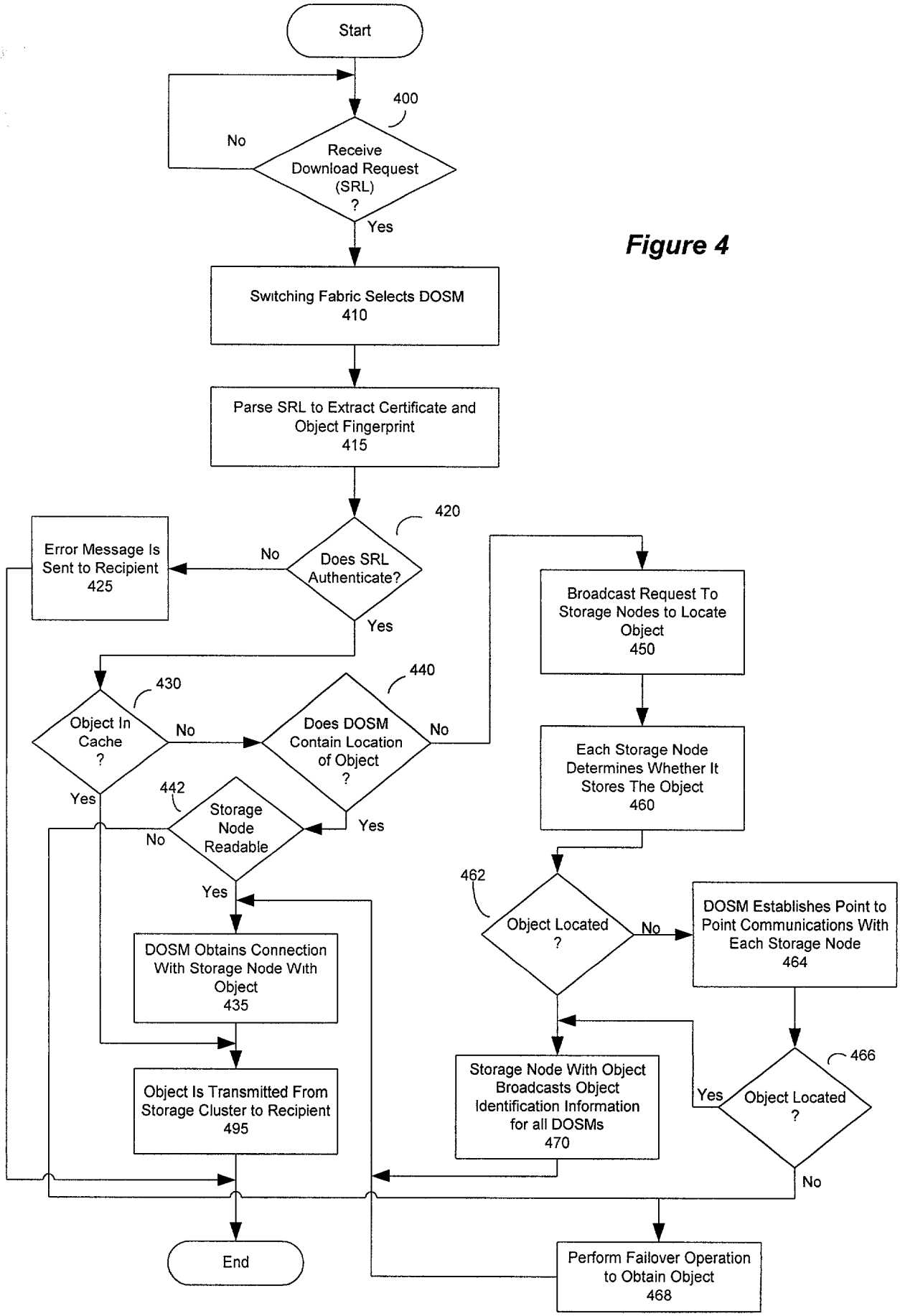

Start
400
Receive Download Request (SRL) ?
No
Yes
Switching Fabric Selects DOSM 410
Parse SRL to Extract Certificate and Object Fingerprint 415
420
Does SRL Authenticate?
No
Error Message Is Sent to Recipient 425
Yes
430
Object In Cache ?
No
440
Does DOSM Contain Location of Object ?
No
Yes
442
Storage Node Readable
No
Yes
Yes
DOSM Obtains Connection With Storage Node With Object 435
Object Is Transmitted From Storage Cluster to Recipient 495
End
Broadcast Request To Storage Nodes to Locate Object 450
Each Storage Node Determines Whether It Stores The Object 460
462
Object Located ?
No
DOSM Establishes Point to Point Communications With Each Storage Node 464
Storage Node With Object Broadcasts Object Identification Information for all DOSMs 470
466
Yes
Object Located ?
No
Perform Failover Operation to Obtain Object 468

Figure 4

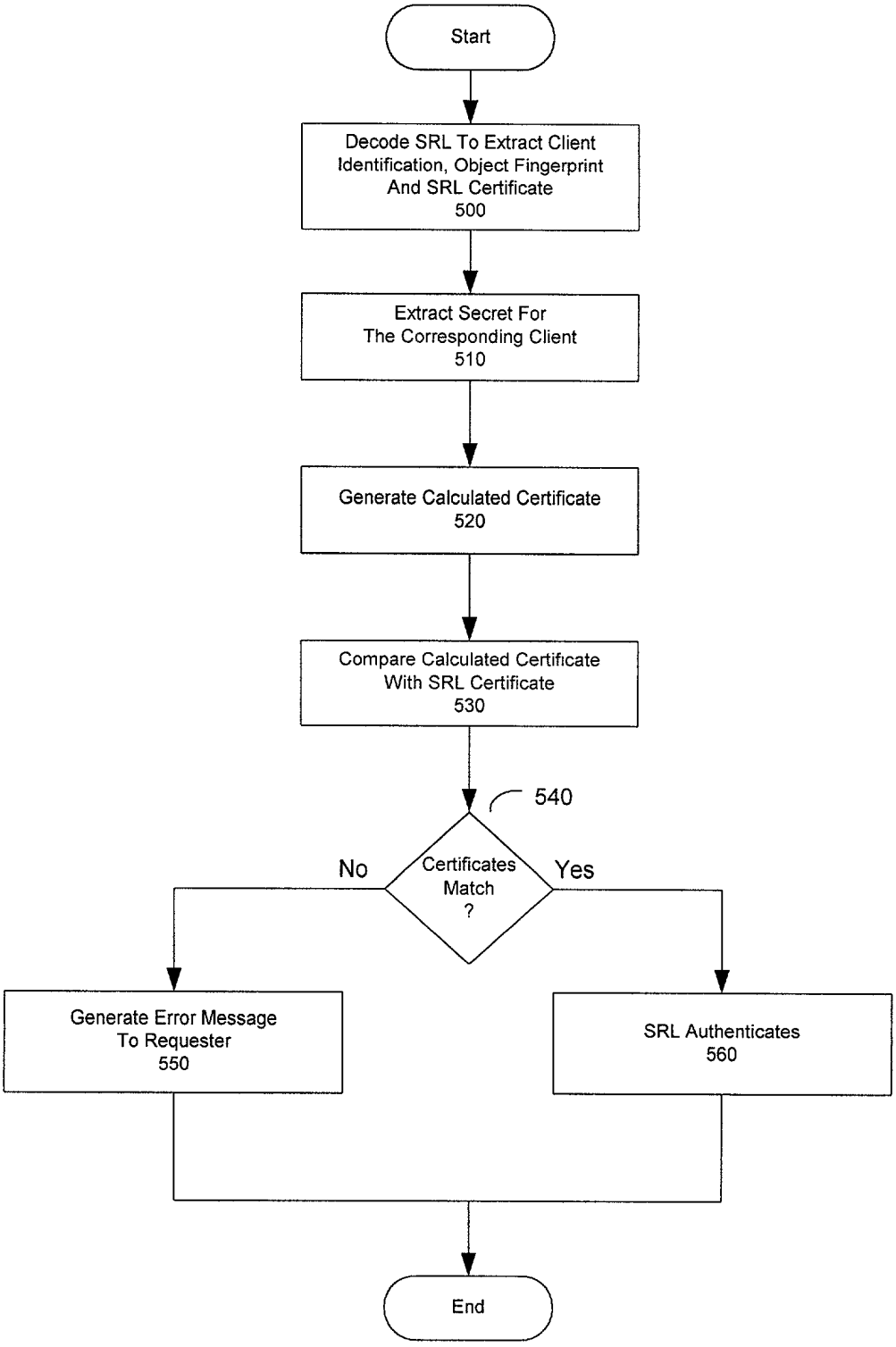
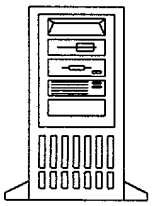

Start
Decode SRL To Extract Client Identification, Object Fingerprint And SRL Certificate
500
Extract Secret For The Corresponding Client
510
Generate Calculated Certificate
520
Compare Calculated Certificate With SRL Certificate
530
540
Certificates Match ?
No
Yes
Generate Error Message To Requester
550
SRL Authenticates
560
End

Figure 5

DOSM File Look-up Table
610

File Id	IP Addr	Disk Id
file1.MD5	10.3.100.1	3
file2.MD5	10.3.098.1	1
file3.MD5	10.3.050.1	6
file4.MD5	10.3.100.1	2
file5.MD5	10.3.098.1	1
file6.MD5	10 3.050 1	8



DOSM Server
600

Data Cache
620

Film Snippet

Advertisement

Film Preview

State Table
630

Read - Write State of Storage Nodes
Health of Storage Nodes
Load of Storage Nodes - Storage Capacity - Number of I/O Operations Per Second

Figure 6

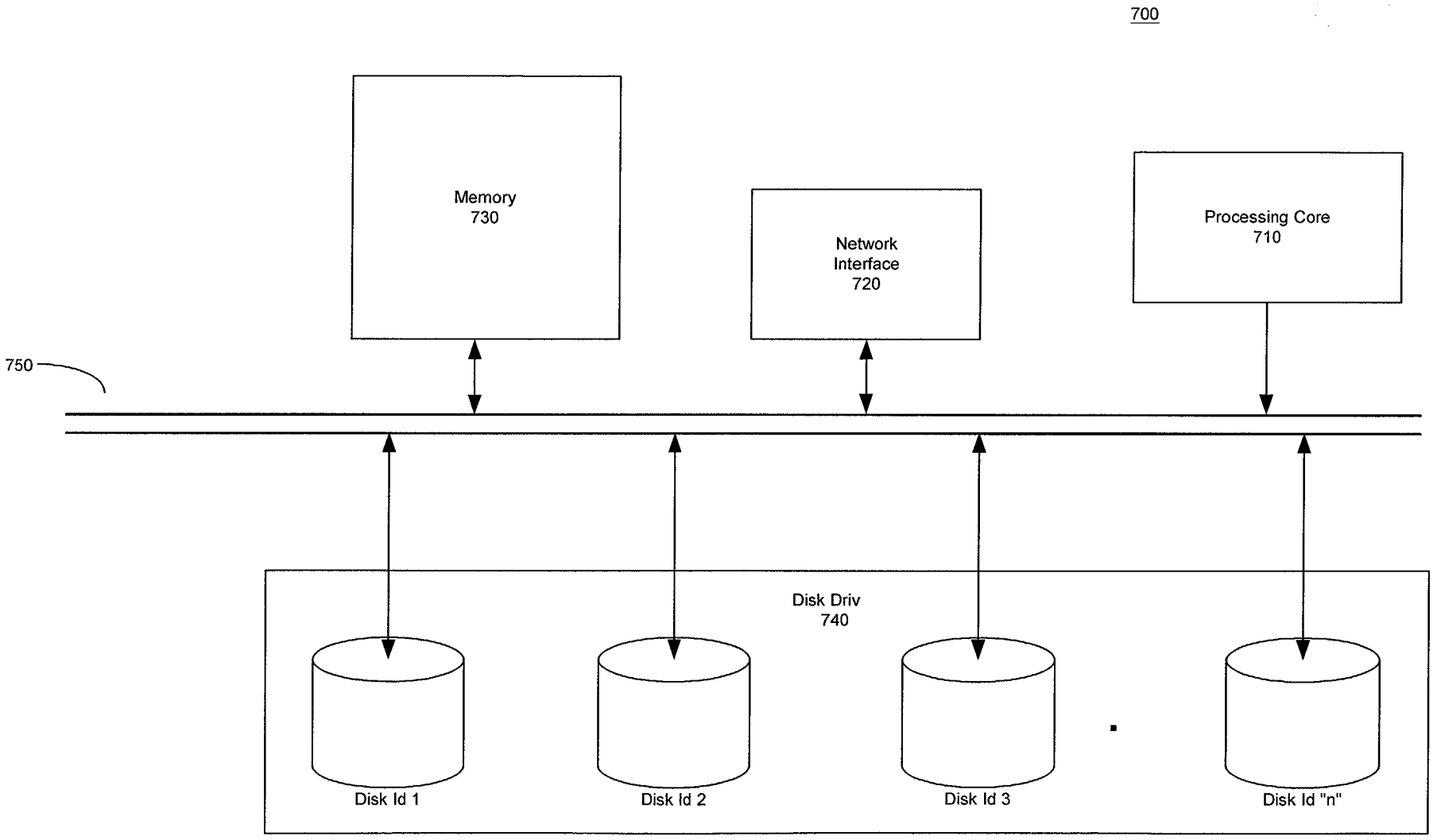

700
Memory
730
Network
Interface
720
Processing Core
710
750
Disk Driv
740
Disk Id 1
Disk Id 2
Disk Id 3
Disk Id "n"

Figure 7

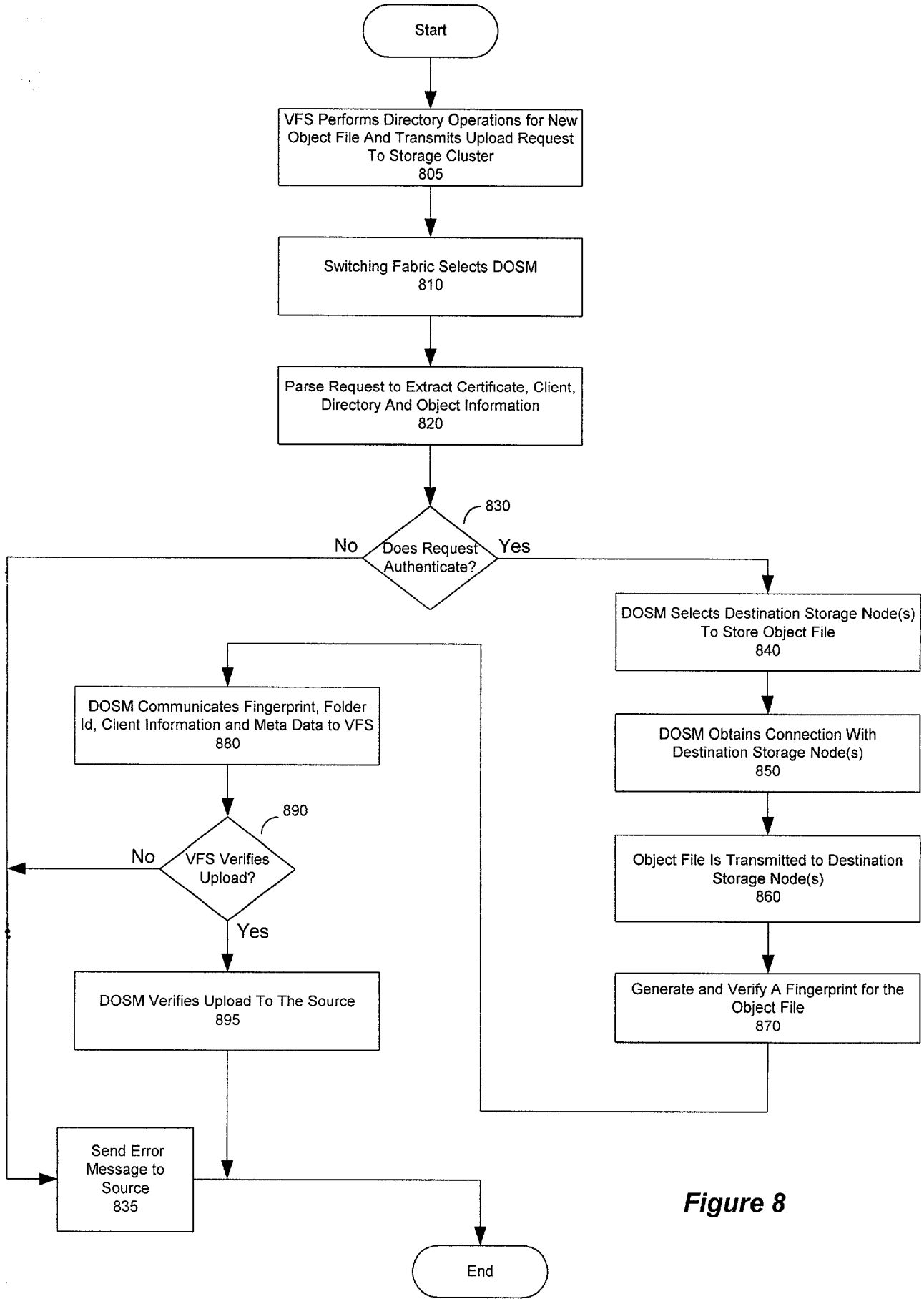

Start
VFS Performs Directory Operations for New Object File And Transmits Upload Request To Storage Cluster
805
Switching Fabric Selects DOSM
810
Parse Request to Extract Certificate, Client, Directory And Object Information
820
830
Does Request Authenticate?
No
Yes
DOSM Selects Destination Storage Node(s) To Store Object File
840
DOSM Obtains Connection With Destination Storage Node(s)
850
Object File Is Transmitted to Destination Storage Node(s)
860
Generate and Verify A Fingerprint for the Object File
870
DOSM Communicates Fingerprint, Folder Id, Client Information and Meta Data to VFS
880
890
VFS Verifies Upload?
No
Yes
DOSM Verifies Upload To The Source
895
Send Error Message to Source
835
End

Figure 8

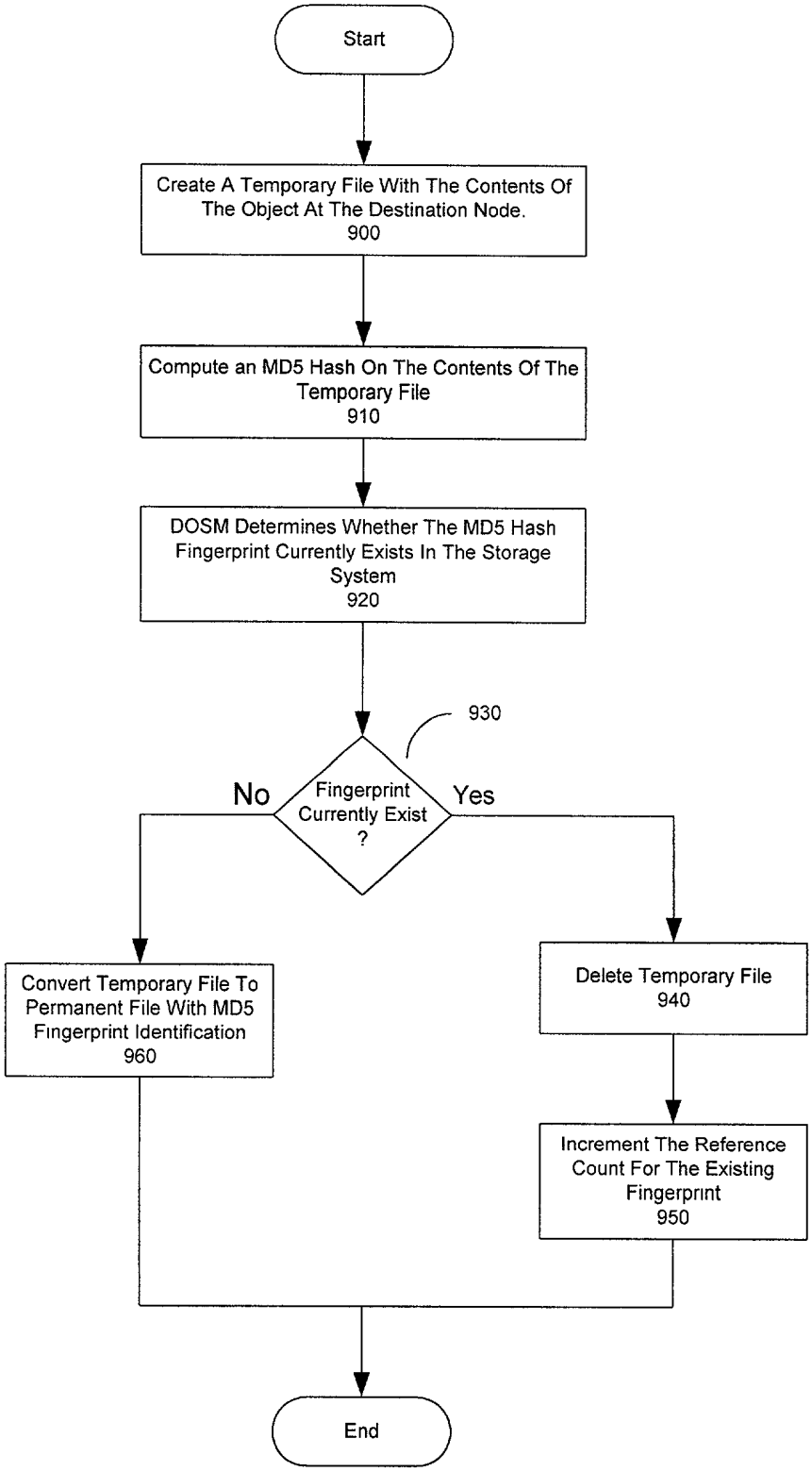

Start
Create A Temporary File With The Contents Of The Object At The Destination Node.
900
Compute an MD5 Hash On The Contents Of The Temporary File
910
DOSM Determines Whether The MD5 Hash Fingerprint Currently Exists In The Storage System
920
930
Fingerprint Currently Exist ?
No
Yes
Convert Temporary File To Permanent File With MD5 Fingerprint Identification
960
Delete Temporary File
940
Increment The Reference Count For The Existing Fingerprint
950
End

Figure 9

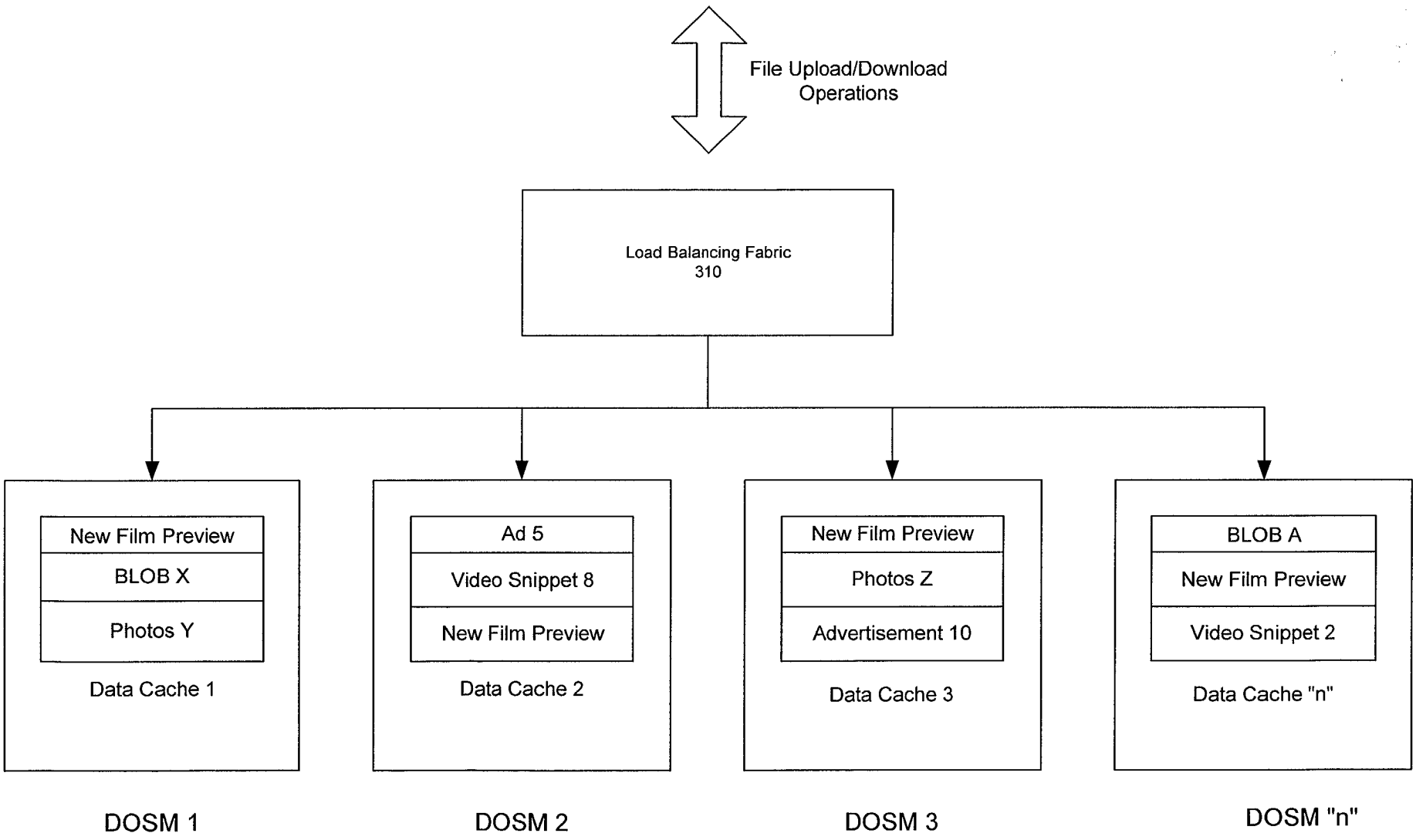

File Upload/Download Operations
Load Balancing Fabric 310
New Film Preview
BLOB X
Photos Y
Data Cache 1
Ad 5
Video Snippet 8
New Film Preview
Data Cache 2
New Film Preview
Photos Z
Advertisement 10
Data Cache 3
BLOB A
New Film Preview
Video Snippet 2
Data Cache "n"
DOSM 1
DOSM 2
DOSM 3
DOSM "n"

Figure 10

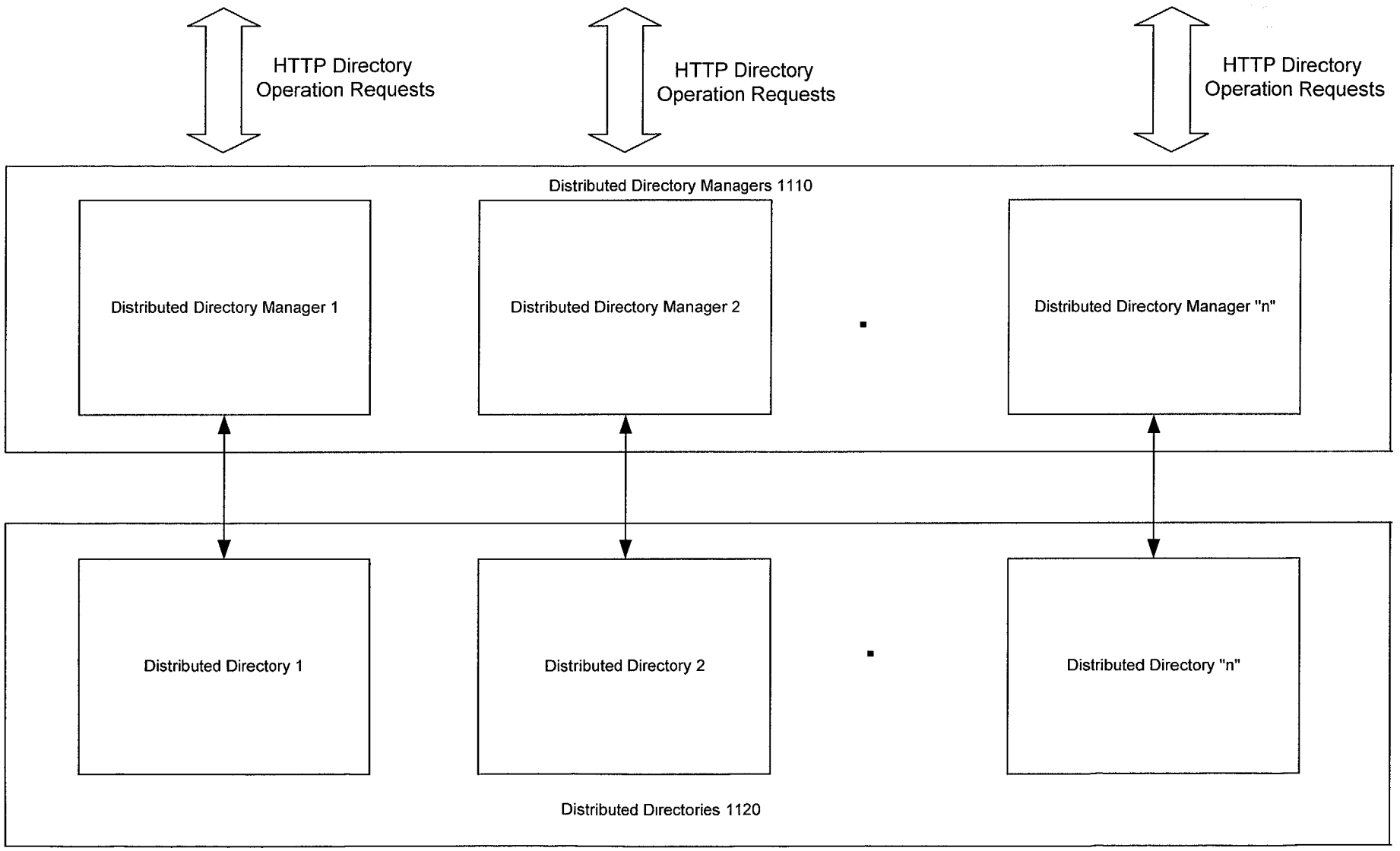

HTTP Directory Operation Requests
HTTP Directory Operation Requests
HTTP Directory Operation Requests
Distributed Directory Managers 1110
Distributed Directory Manager 1
Distributed Directory Manager 2
Distributed Directory Manager "n"
Distributed Directory 1
Distributed Directory 2
Distributed Directory "n"
Distributed Directories 1120
1100

Figure 11

Customer Table

	Customer Name	Customer Reserved Fields
	Customer A	[Customer stores data ...]
	Customer B	[Customer stores data ...]
	Customer C	[Customer stores data ...]
	Customer D	[Customer stores data ...]

1200

Folder Table

Customer Id	Folder Id	Folder Parent Id	Metadata
3	2	-	[Reserved]
3	100	2	[Reserved]
3	251	2	[Reserved]
3	166	251	[Reserved]

1210

File Table

Customer Id	File Handle	Folder Id	Folder Parent Id	Metadata
3	52.MD5	100	2	[Reserved]
3	55.MD5	100	2	[Reserved]
3	99.MD5	166	251	[Reserved]
3	67.MD5	166	251	[Reserved]

1220

Figure 12

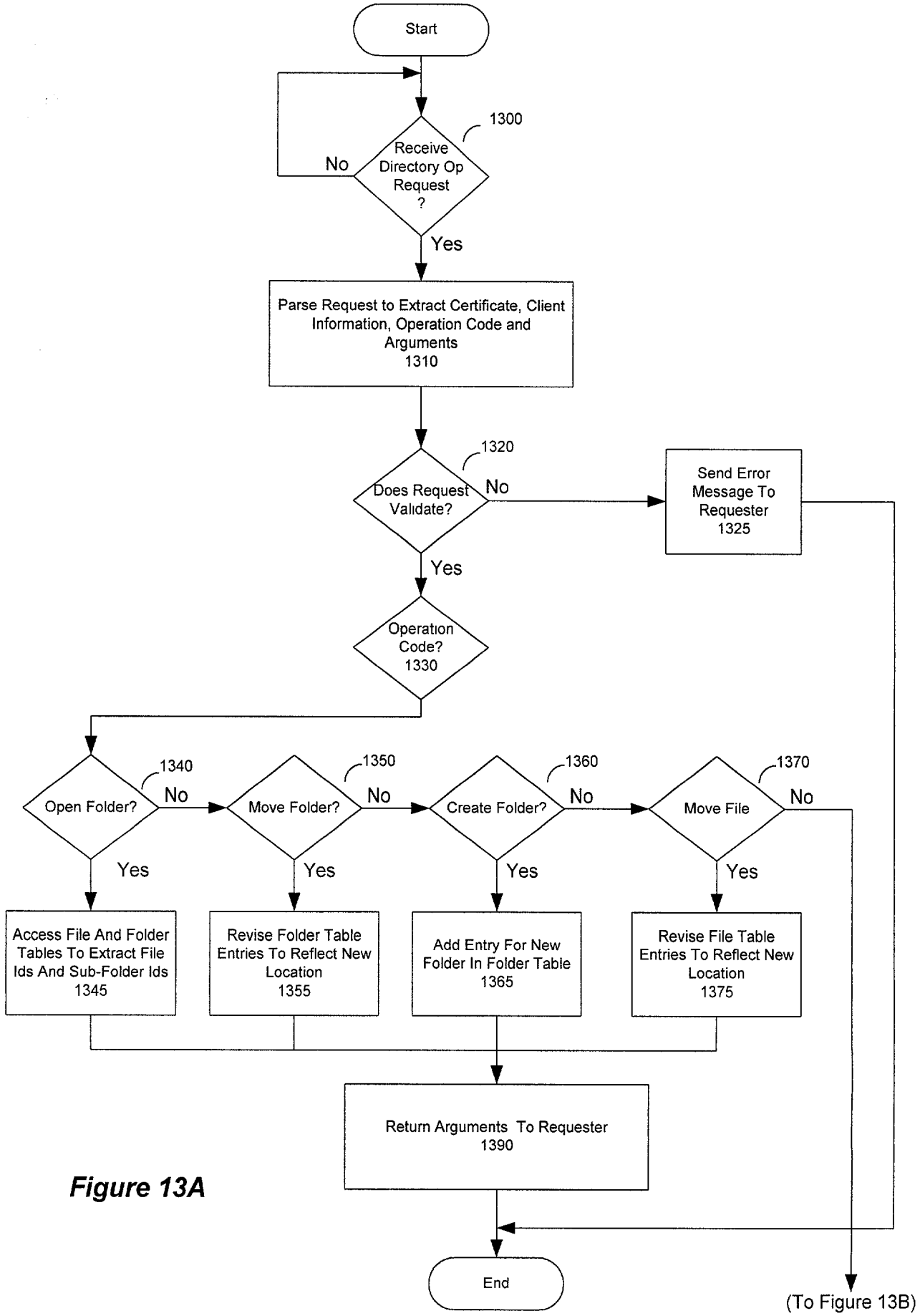

Start
1300
Receive Directory Op Request ?
No
Yes
Parse Request to Extract Certificate, Client Information, Operation Code and Arguments
1310
1320
Does Request Validate?
No
Send Error Message To Requester
1325
Yes
Operation Code?
1330
1340
Open Folder?
No
1350
Move Folder?
No
1360
Create Folder?
No
1370
Move File
No
Yes
Yes
Yes
Yes
Access File And Folder Tables To Extract File Ids And Sub-Folder Ids
1345
Revise Folder Table Entries To Reflect New Location
1355
Add Entry For New Folder In Folder Table
1365
Revise File Table Entries To Reflect New Location
1375
Return Arguments To Requester
1390
End
(To Figure 13B)

Figure 13A

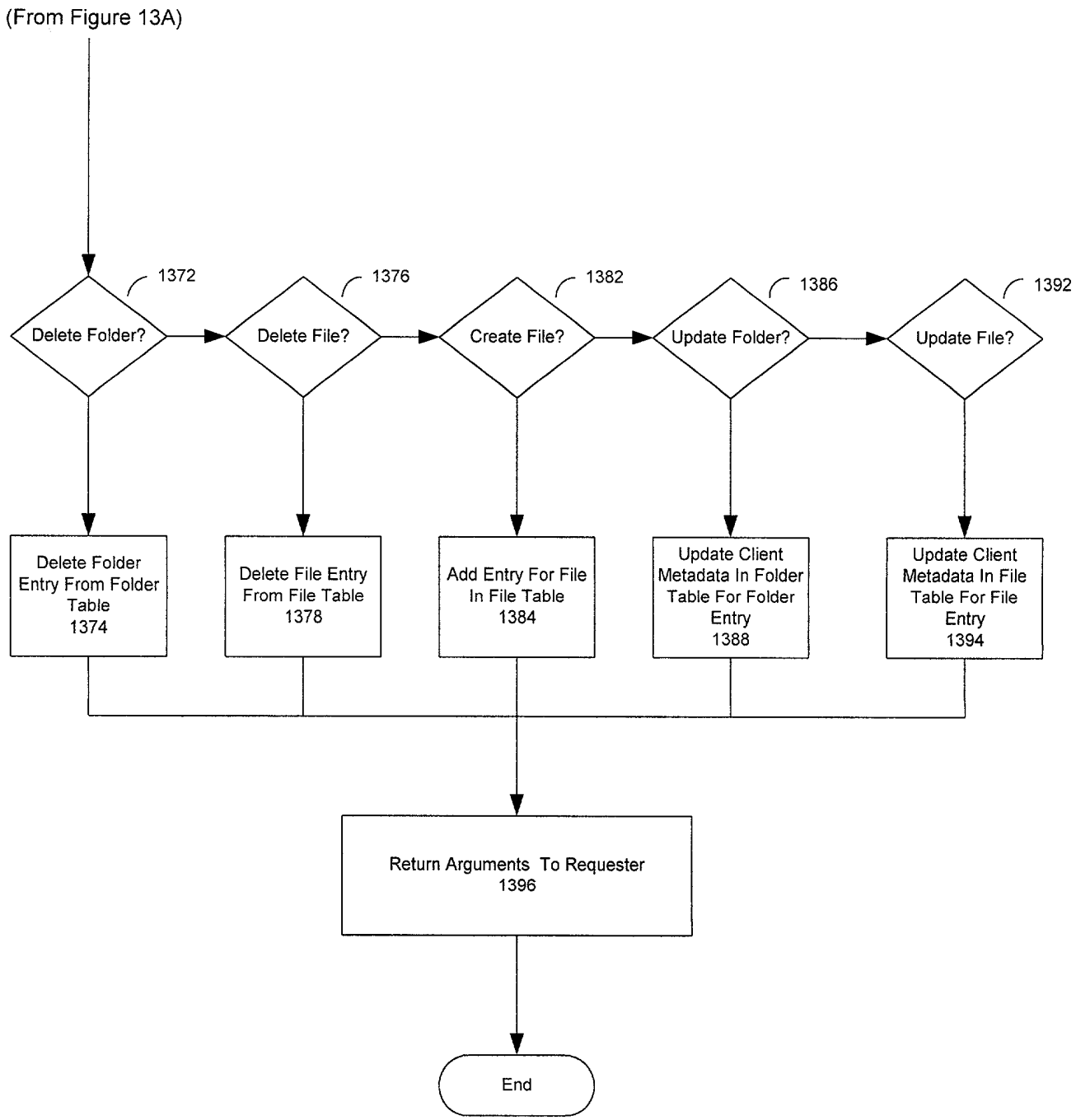

(From Figure 13A)
1372
Delete Folder?
1376
Delete File?
1382
Create File?
1386
Update Folder?
1392
Update File?
Delete Folder Entry From Folder Table 1374
Delete File Entry From File Table 1378
Add Entry For File In File Table 1384
Update Client Metadata In Folder Table For Folder Entry 1388
Update Client Metadata In File Table For File Entry 1394
Return Arguments To Requester 1396
End

Figure 13B

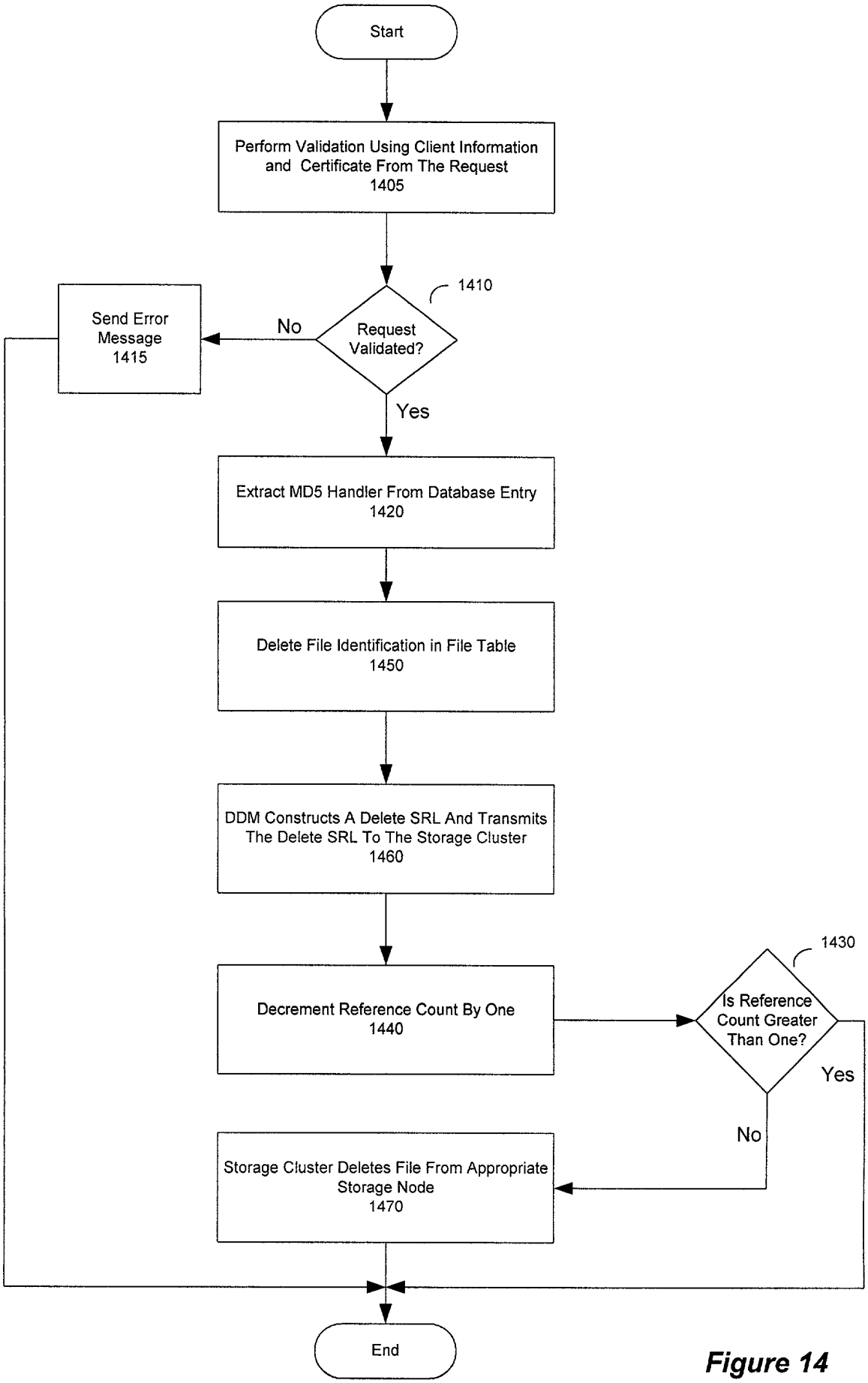

Start
Perform Validation Using Client Information and Certificate From The Request
1405
1410
Request Validated?
No
Send Error Message
1415
Yes
Extract MD5 Handler From Database Entry
1420
Delete File Identification in File Table
1450
DDM Constructs A Delete SRL And Transmits The Delete SRL To The Storage Cluster
1460
Decrement Reference Count By One
1440
1430
Is Reference Count Greater Than One?
Yes
No
Storage Cluster Deletes File From Appropriate Storage Node
1470
End

Figure 14

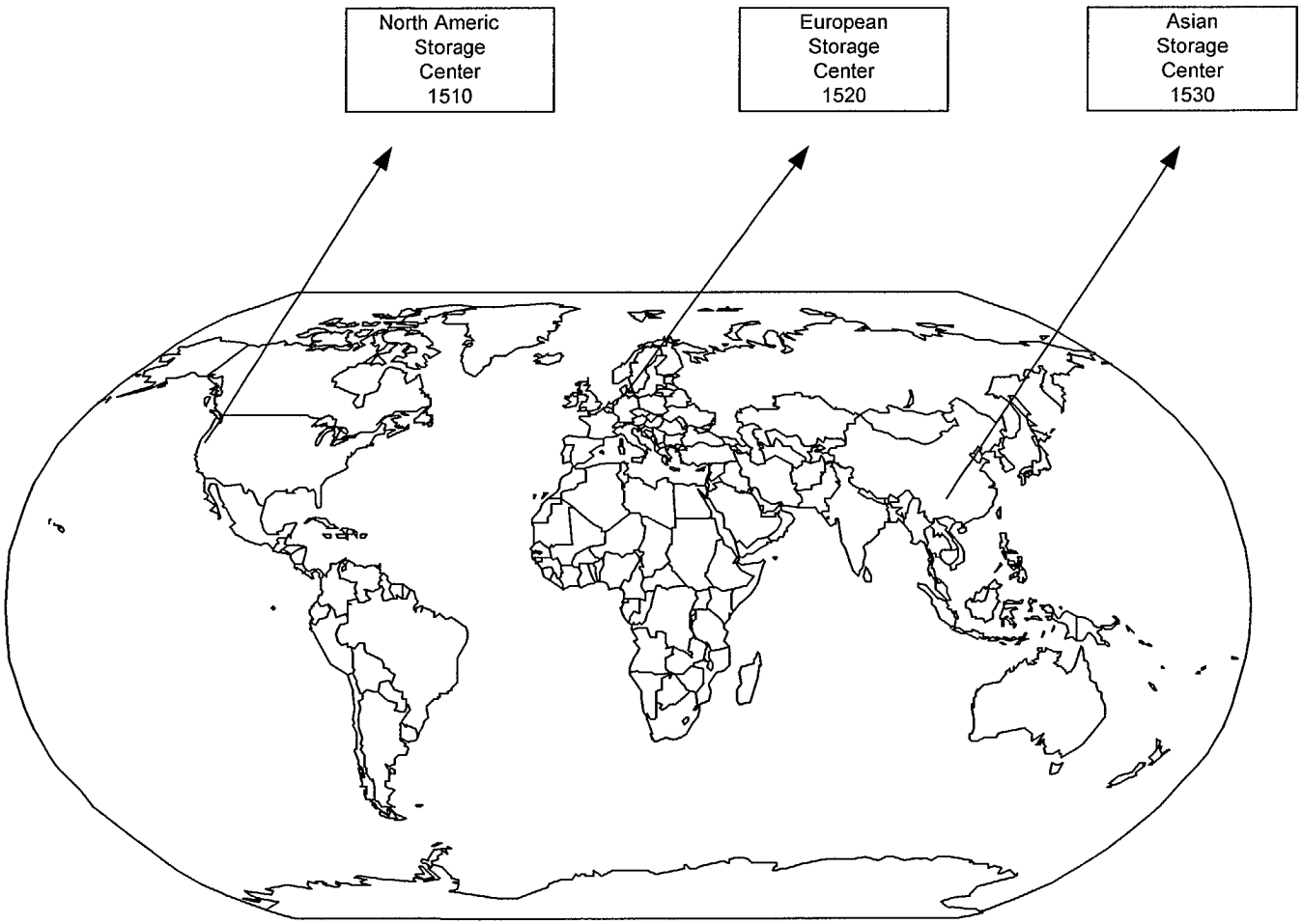

North Americ
Storage
Center
1510
European
Storage
Center
1520
Asian
Storage
Center
1530

Figure 15

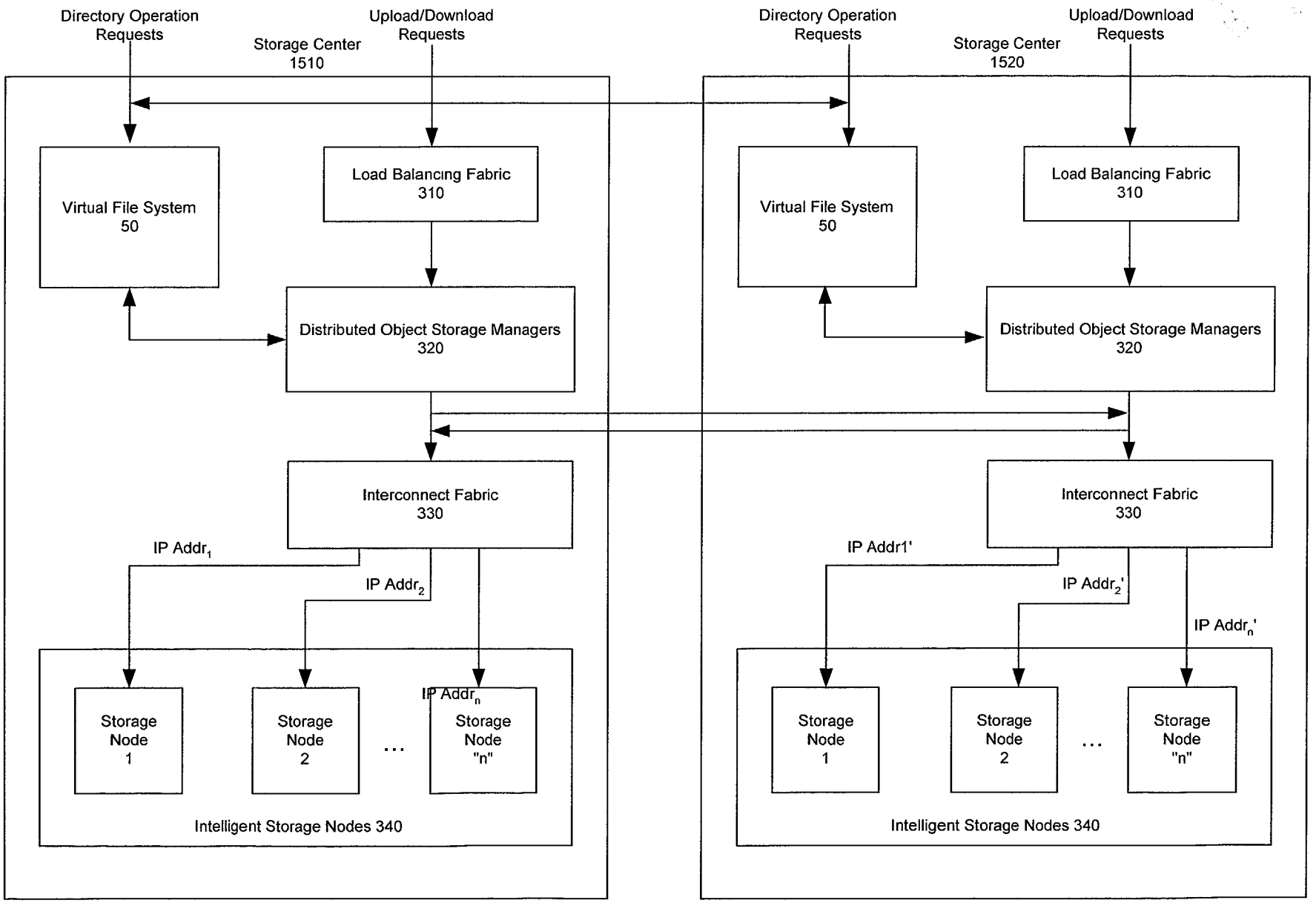

Directory Operation Requests
Upload/Download Requests
Storage Center 1510
Virtual File System 50
Load Balancing Fabric 310
Distributed Object Storage Managers 320
Interconnect Fabric 330
IP Addr1
IP Addr2
IP Addrn
Storage Node 1
Storage Node 2
Storage Node "n"
Intelligent Storage Nodes 340
Directory Operation Requests
Upload/Download Requests
Storage Center 1520
Virtual File System 50
Load Balancing Fabric 310
Distributed Object Storage Managers 320
Interconnect Fabric 330
IP Addr1'
IP Addr2'
IP Addrn'
Storage Node 1
Storage Node 2
Storage Node "n"
Intelligent Storage Nodes 340

Figure 16

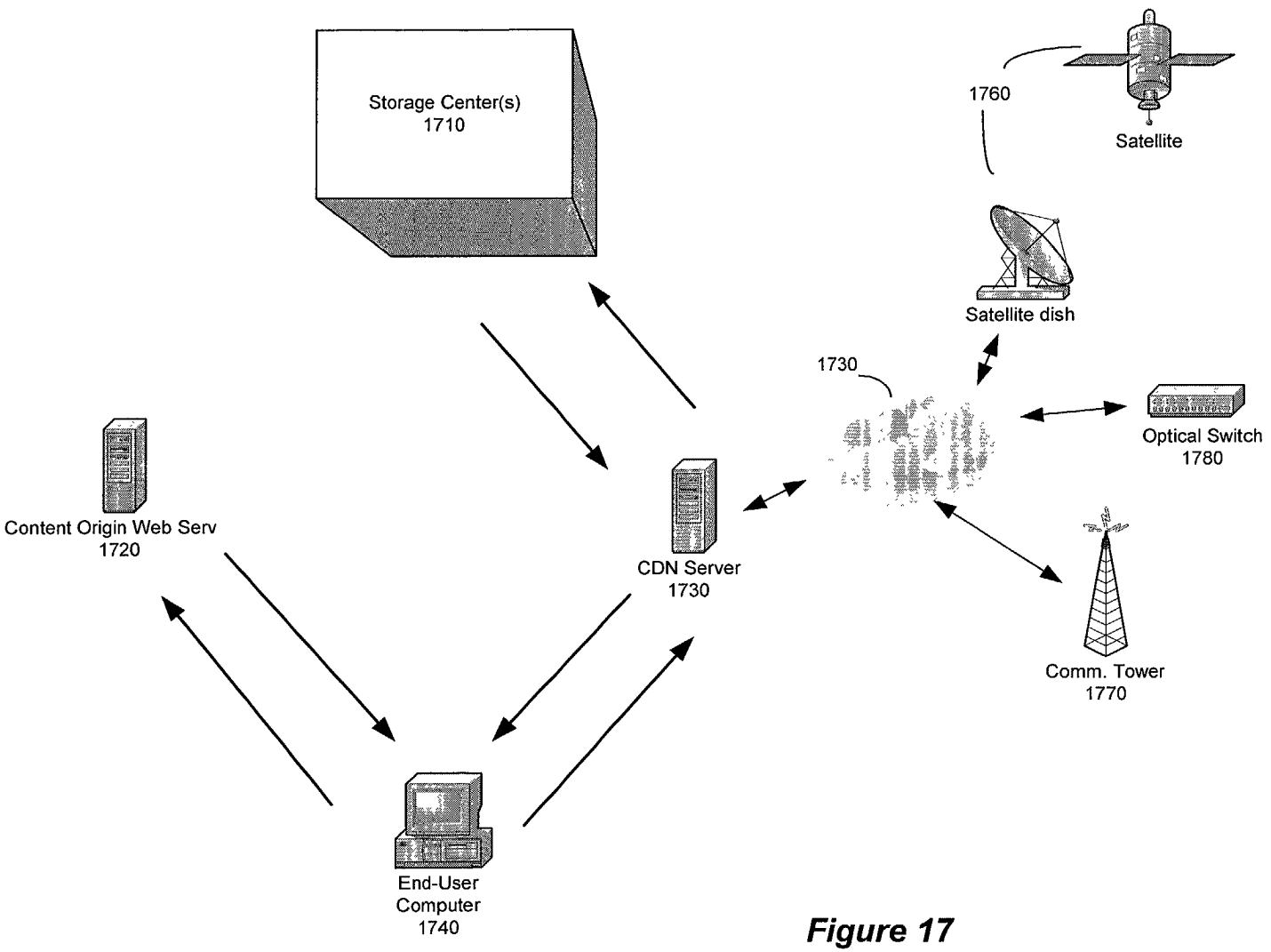

Storage Center(s)
1710
1760
Satellite
Satellite dish
1730
Optical Switch
1780
Content Origin Web Serv
1720
CDN Server
1730
Comm. Tower
1770
End-User
Computer
1740

Figure 17

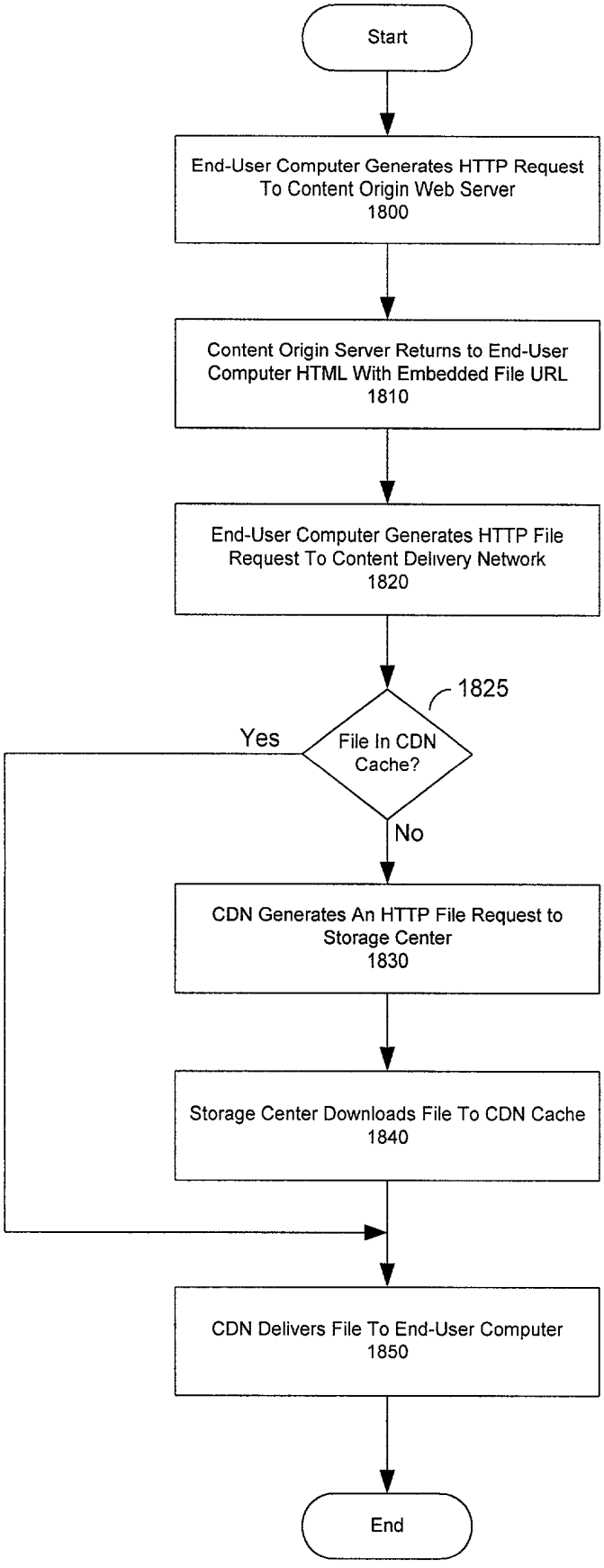

Start
End-User Computer Generates HTTP Request To Content Origin Web Server
1800
Content Origin Server Returns to End-User Computer HTML With Embedded File URL
1810
End-User Computer Generates HTTP File Request To Content Delivery Network
1820
1825
File In CDN Cache?
Yes
No
CDN Generates An HTTP File Request to Storage Center
1830
Storage Center Downloads File To CDN Cache
1840
CDN Delivers File To End-User Computer
1850
End

Figure 18

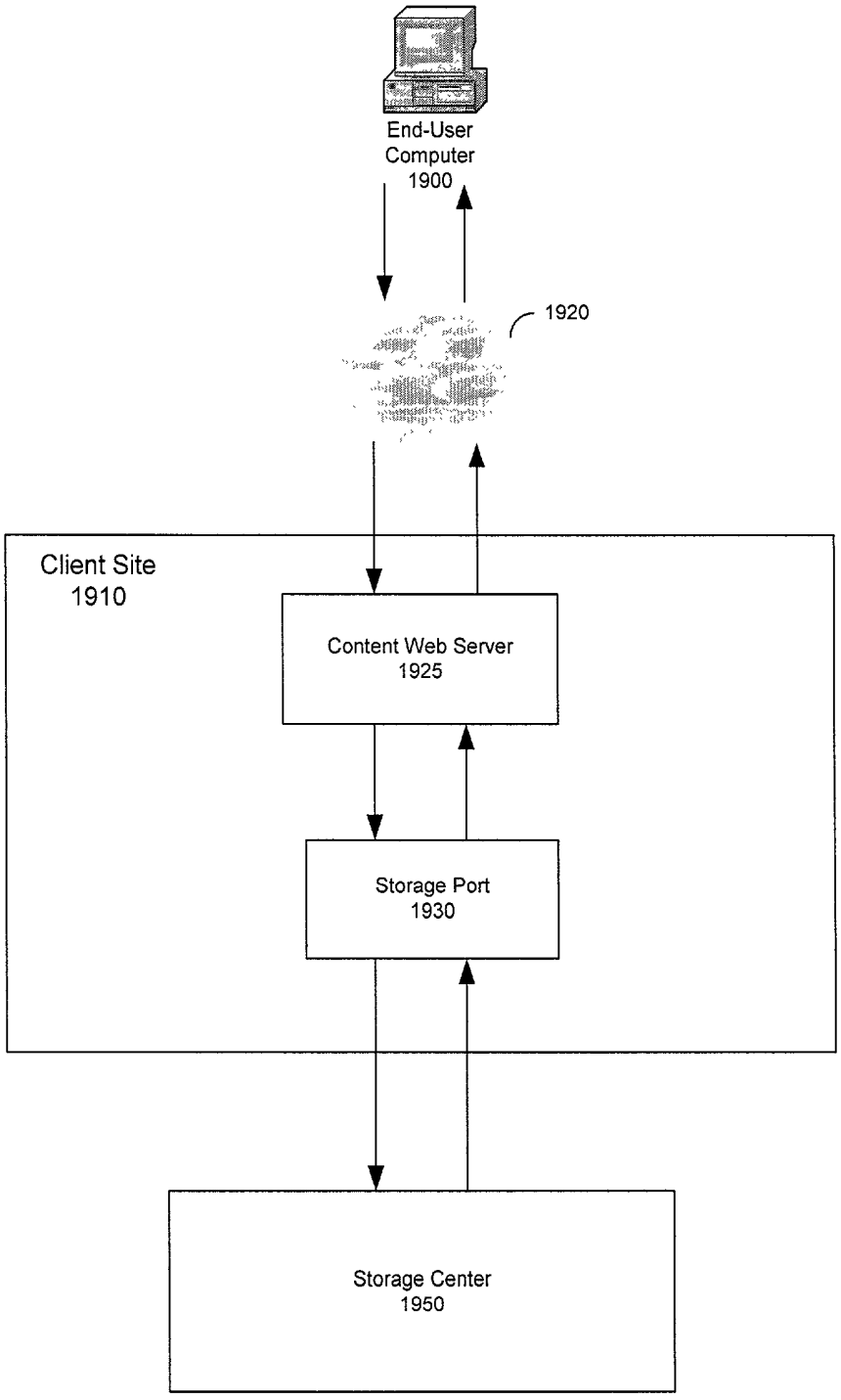

End-User
Computer
1900
1920
Client Site
1910
Content Web Server
1925
Storage Port
1930
Storage Center
1950

Figure 19

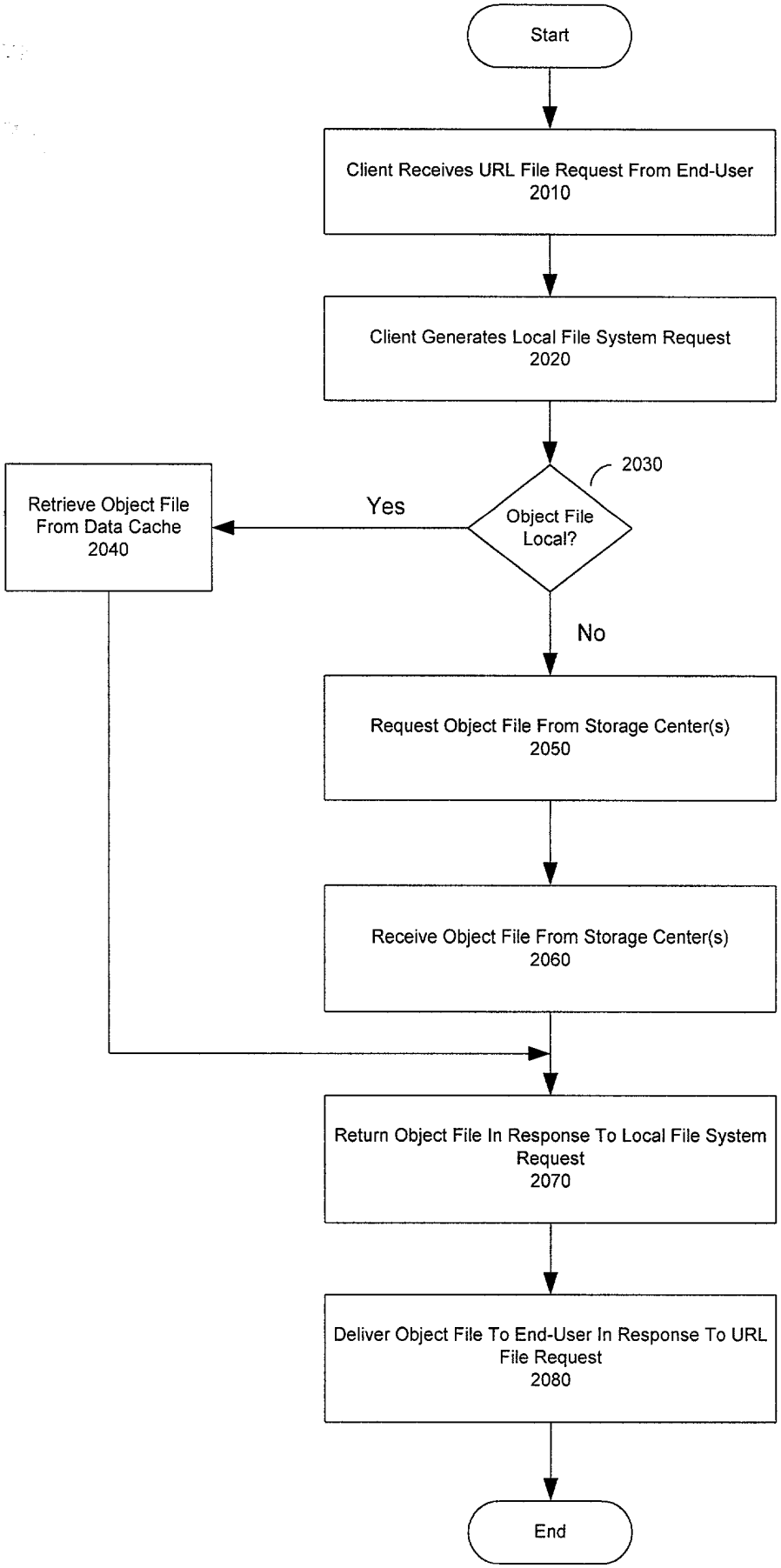

Start
Client Receives URL File Request From End-User
2010
Client Generates Local File System Request
2020
2030
Object File Local?
Yes
Retrieve Object File From Data Cache
2040
No
Request Object File From Storage Center(s)
2050
Receive Object File From Storage Center(s)
2060
Return Object File In Response To Local File System Request
2070
Deliver Object File To End-User In Response To URL File Request
2080
End

Figure 20

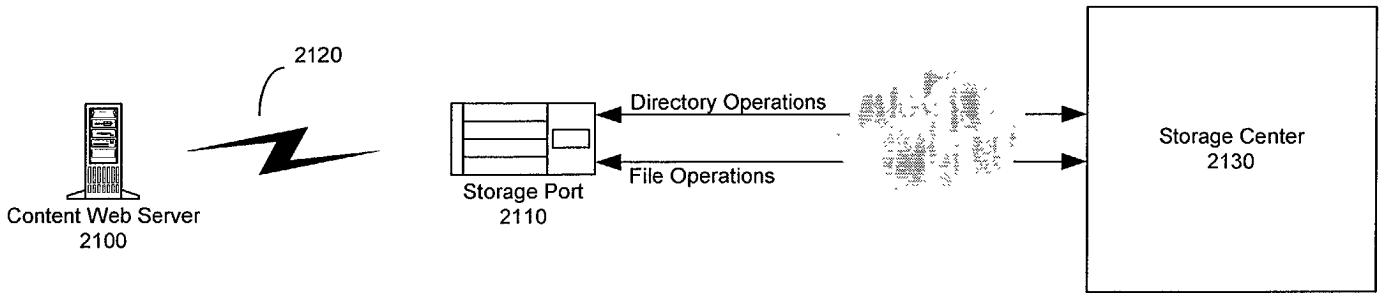


Figure 21a

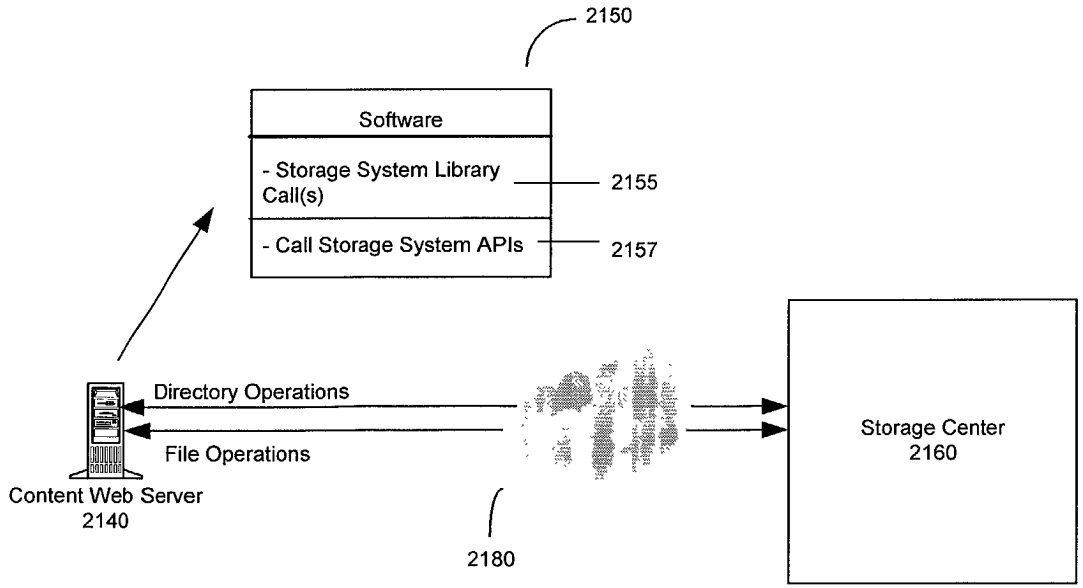


Figure 21b

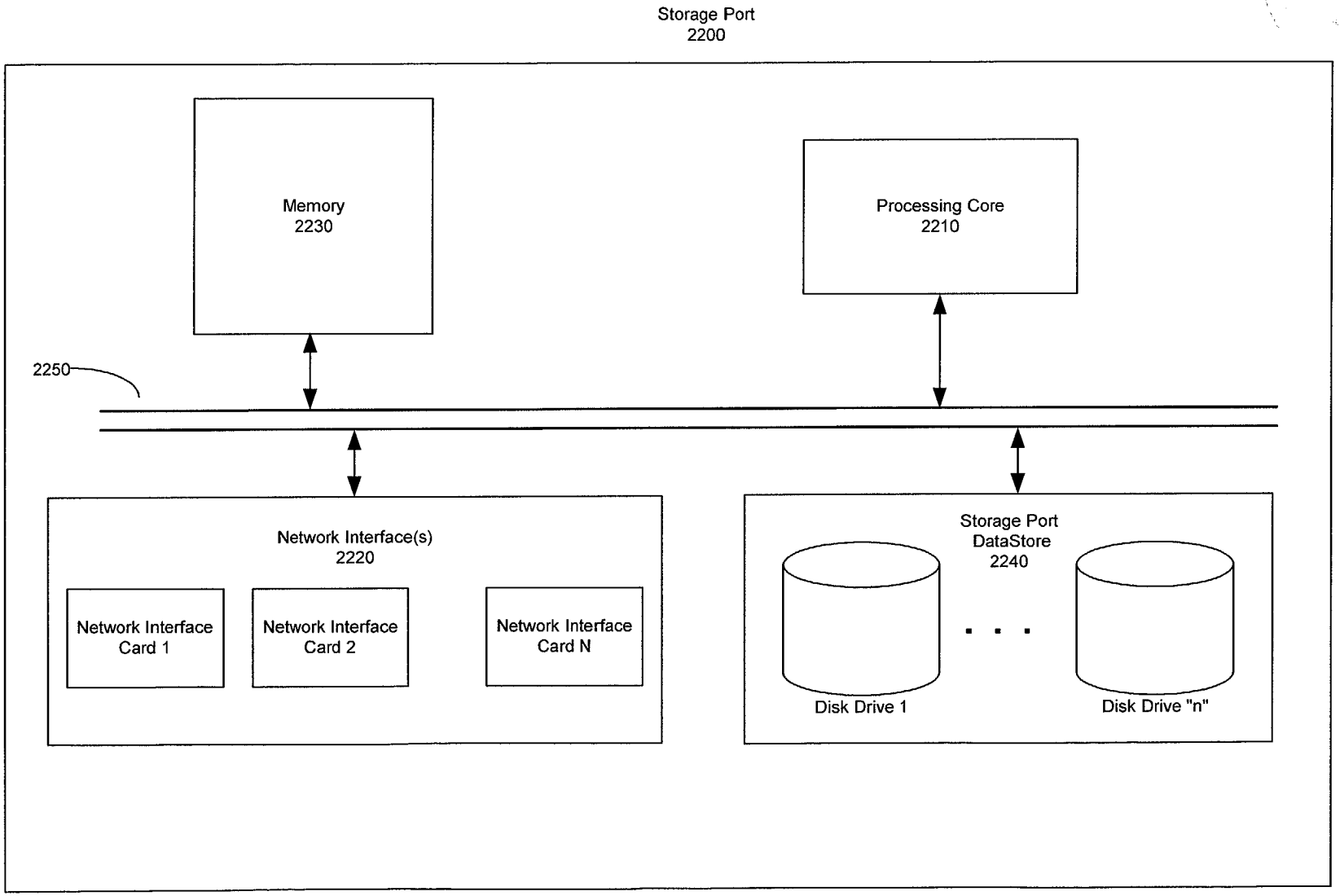

Storage Port
2200
Memory
2230
Processing Core
2210
2250
Network Interface(s)
2220
Network Interface
Card 1
Network Interface
Card 2
Network Interface
Card N
Storage Port
DataStore
2240
Disk Drive 1
Disk Drive "n"

Figure 22

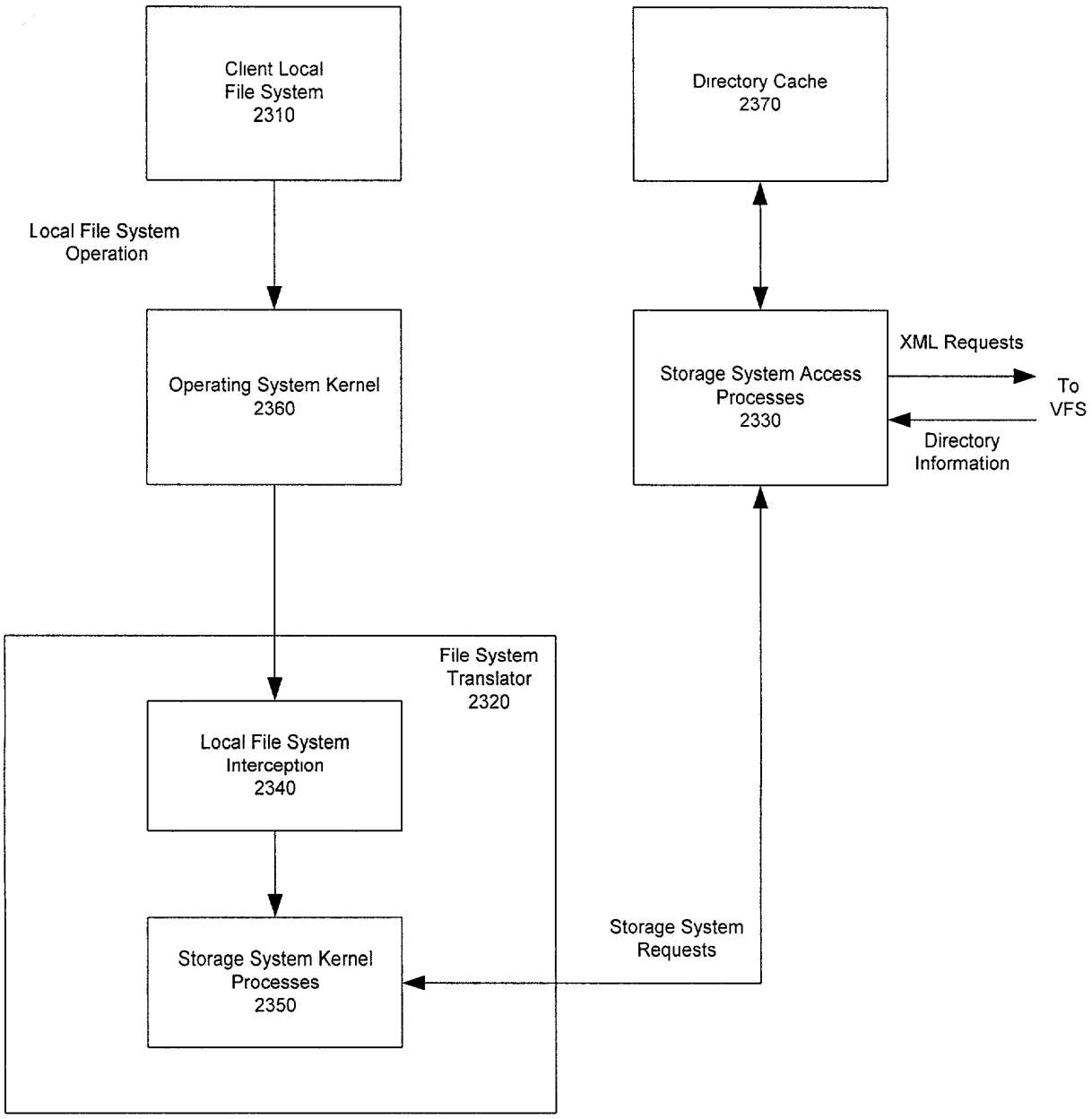


Figure 23

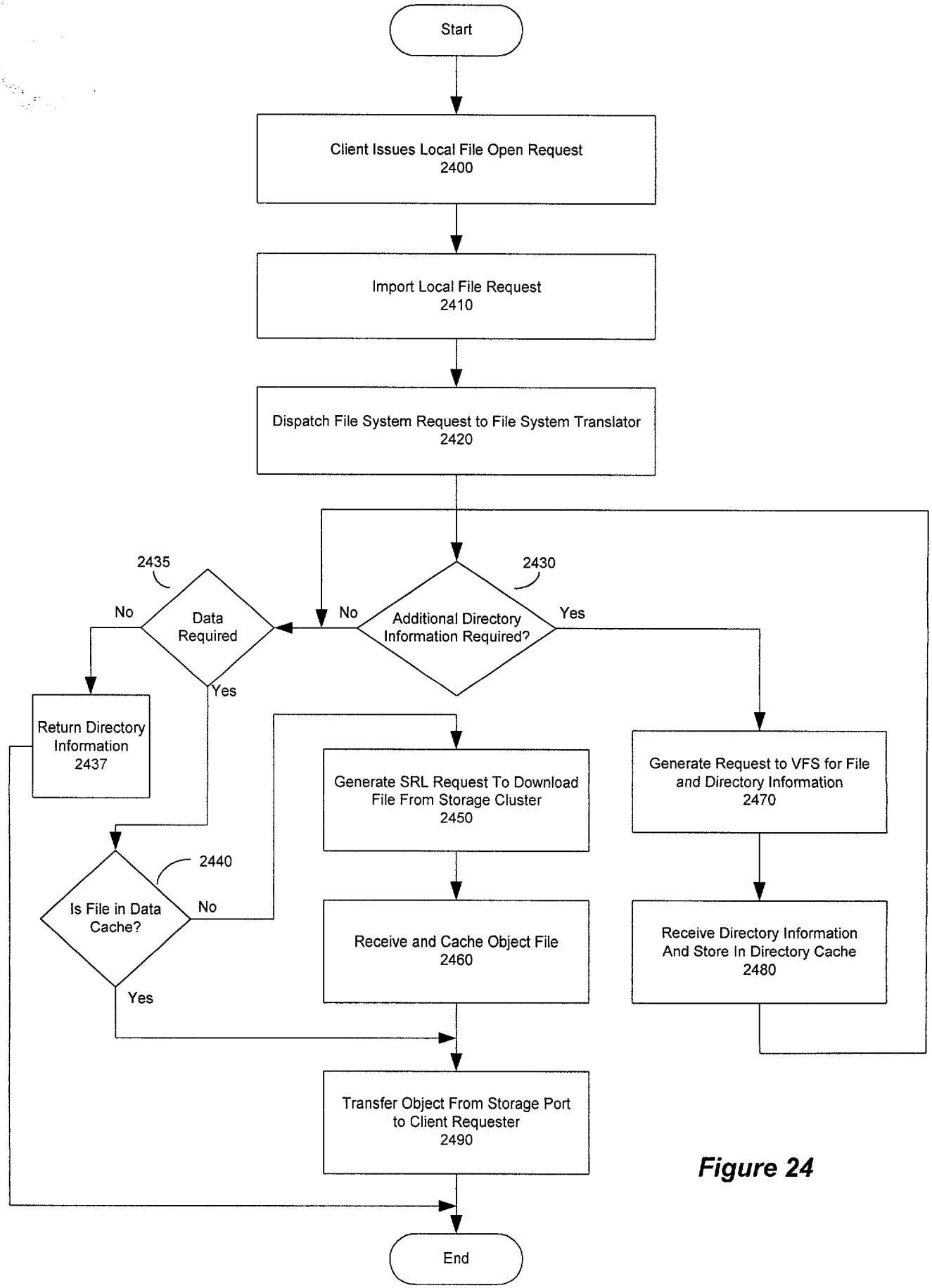

Start
Client Issues Local File Open Request
2400
Import Local File Request
2410
Dispatch File System Request to File System Translator
2420
2435
Data Required
No
Yes
2430
Additional Directory Information Required?
No
Yes
Return Directory Information
2437
2440
Is File in Data Cache?
No
Yes
Generate SRL Request To Download File From Storage Cluster
2450
Receive and Cache Object File
2460
Generate Request to VFS for File and Directory Information
2470
Receive Directory Information And Store In Directory Cache
2480
Transfer Object From Storage Port to Client Requester
2490
End

Figure 24

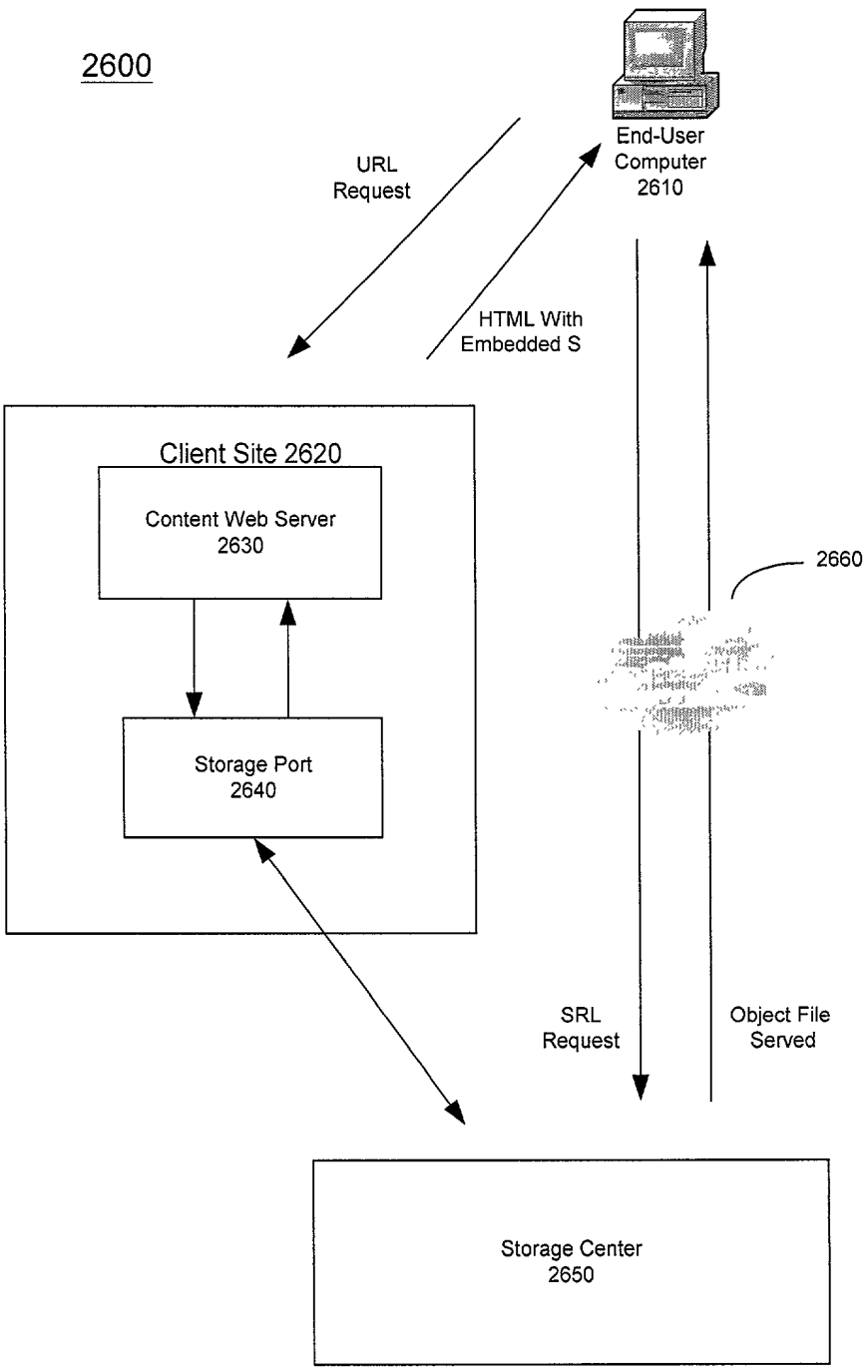

2600
End-User
Computer
2610
URL
Request
HTML With
Embedded S
Client Site 2620
Content Web Server
2630
Storage Port
2640
2660
SRL
Request
Object File
Served
Storage Center
2650

Figure 25

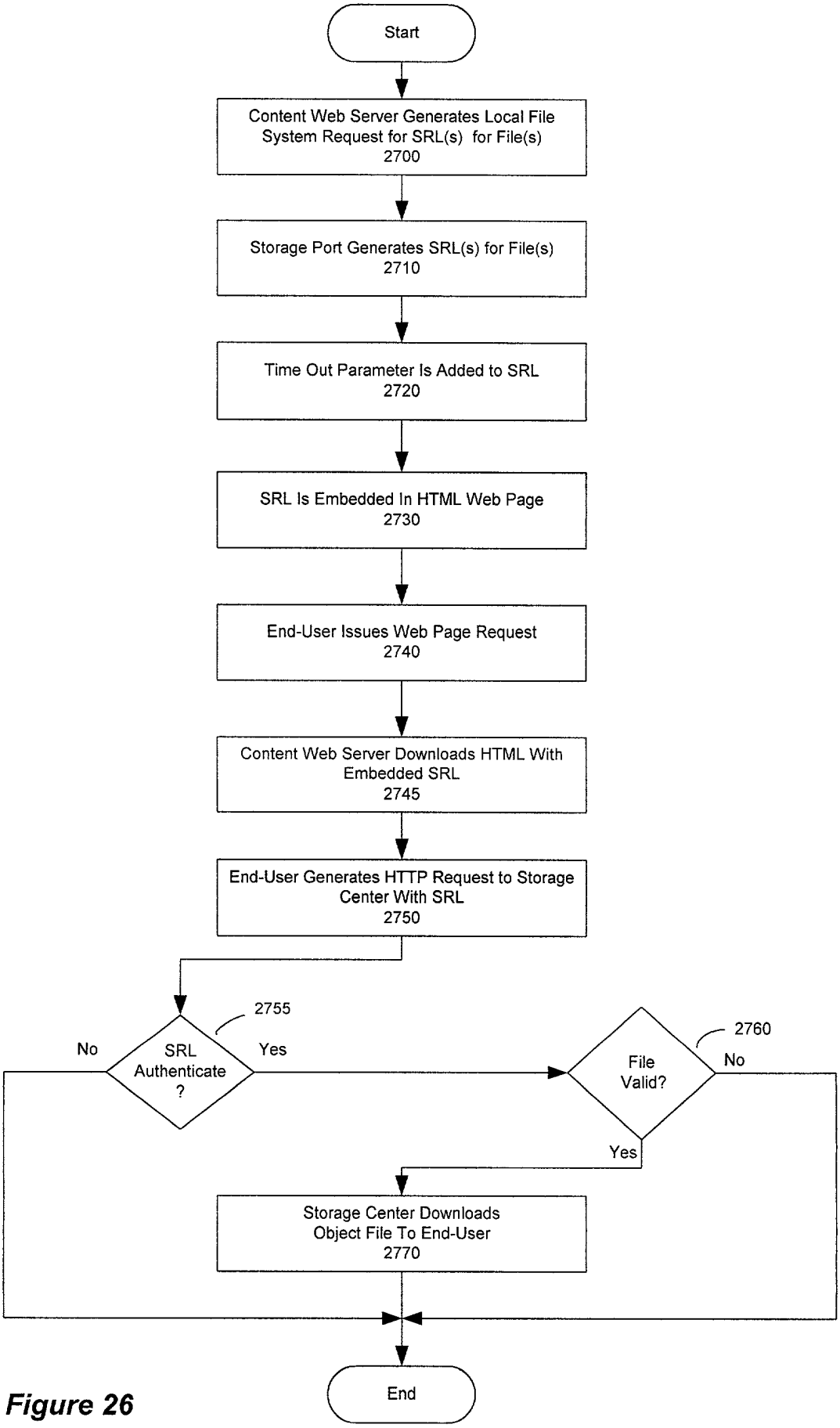

Start
Content Web Server Generates Local File System Request for SRL(s) for File(s)
2700
Storage Port Generates SRL(s) for File(s)
2710
Time Out Parameter Is Added to SRL
2720
SRL Is Embedded In HTML Web Page
2730
End-User Issues Web Page Request
2740
Content Web Server Downloads HTML With Embedded SRL
2745
End-User Generates HTTP Request to Storage Center With SRL
2750
2755
SRL Authenticate ?
No
Yes
2760
File Valid?
No
Yes
Storage Center Downloads Object File To End-User
2770
End

Figure 26

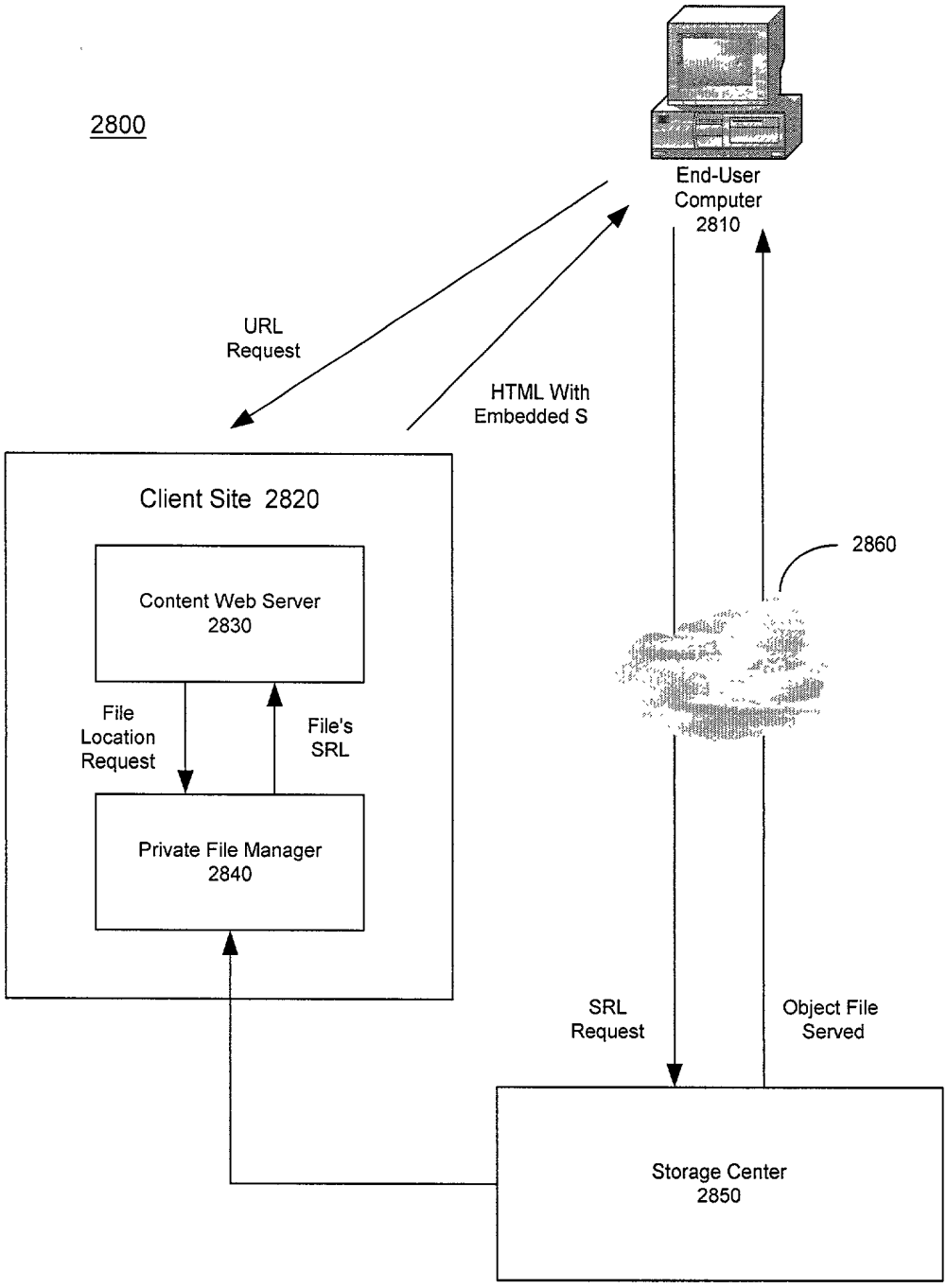

2800
End-User
Computer
2810
URL
Request
HTML With
Embedded S
Client Site 2820
Content Web Server
2830
File
Location
Request
File's
SRL
Private File Manager
2840
2860
SRL
Request
Object File
Served
Storage Center
2850

Figure 27

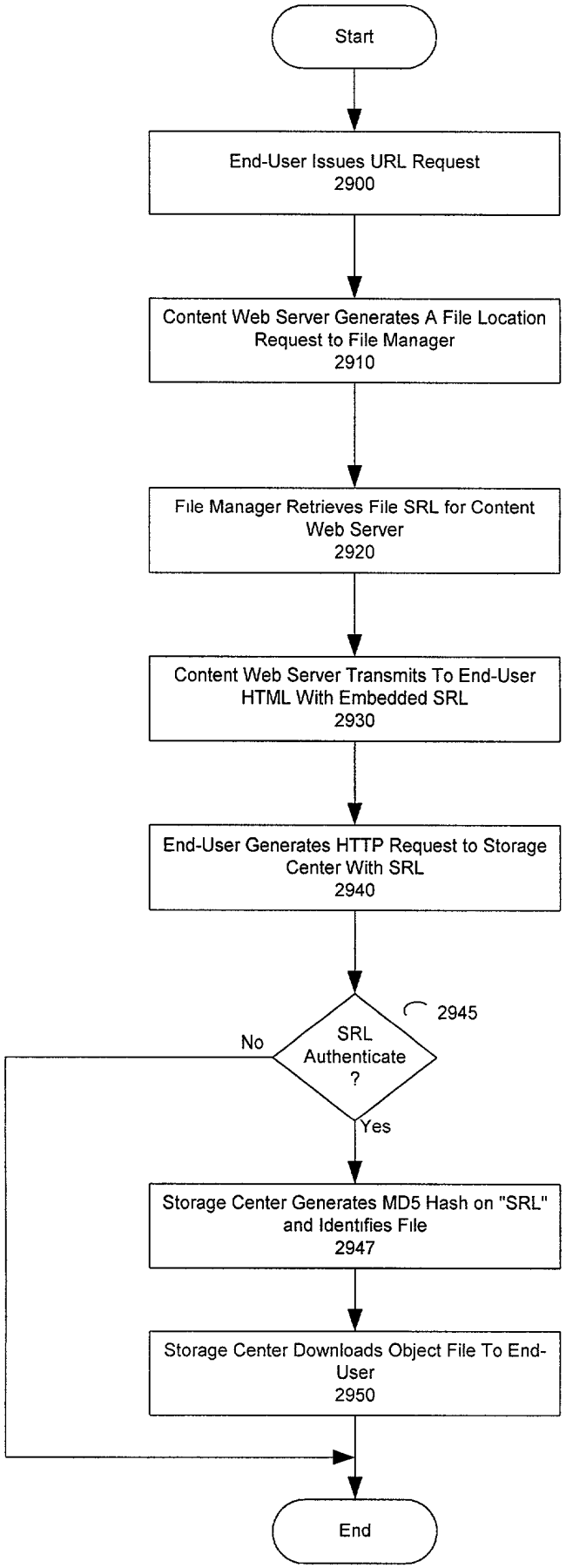

Start
End-User Issues URL Request
2900
Content Web Server Generates A File Location Request to File Manager
2910
File Manager Retrieves File SRL for Content Web Server
2920
Content Web Server Transmits To End-User HTML With Embedded SRL
2930
End-User Generates HTTP Request to Storage Center With SRL
2940
2945
SRL Authenticate ?
No
Yes
Storage Center Generates MD5 Hash on "SRL" and Identifies File
2947
Storage Center Downloads Object File To End-User
2950
End

Figure 28

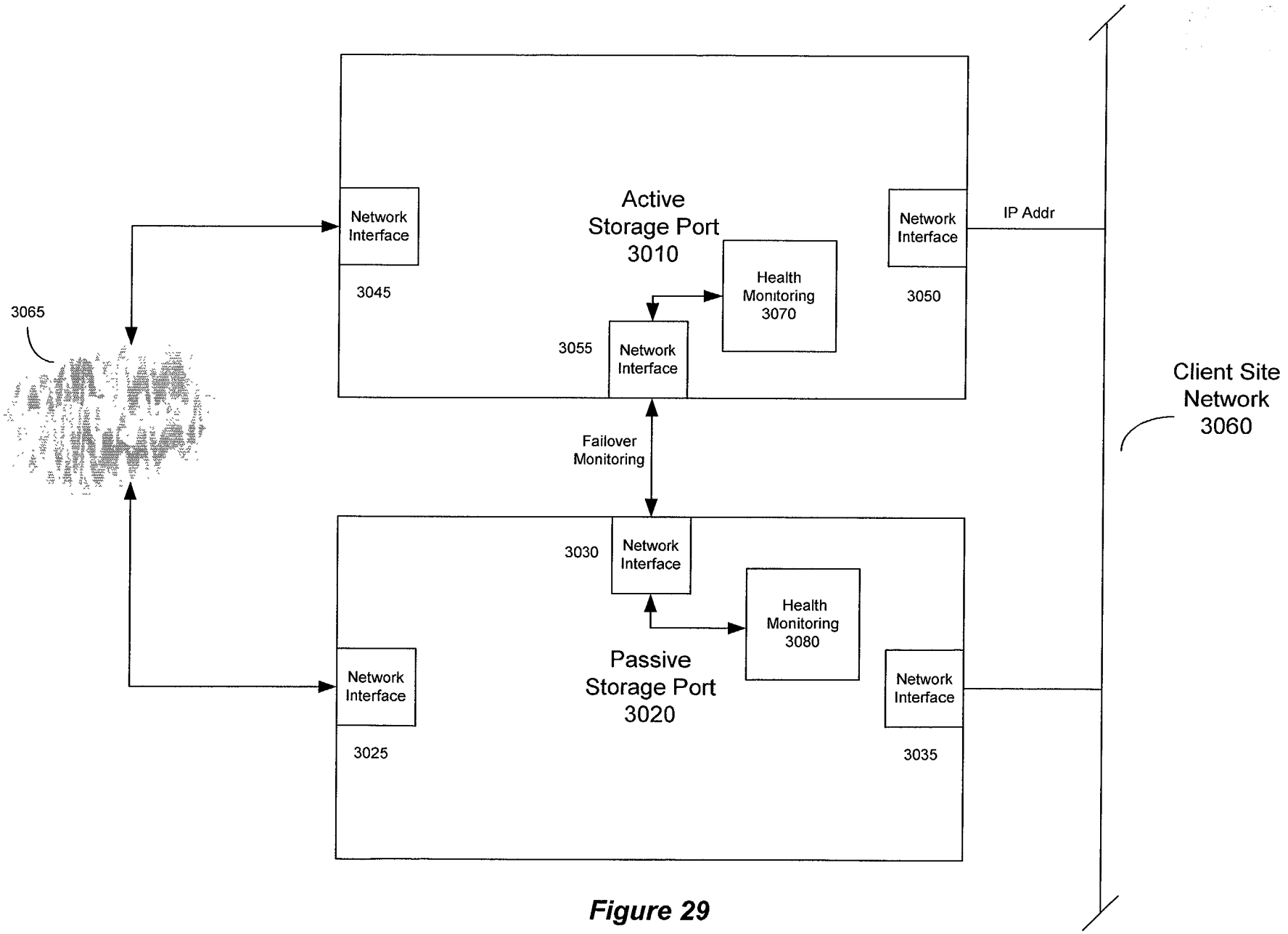

Active
Storage Port
3010
Network
Interface
3045
Network
Interface
3050
IP Addr
Health
Monitoring
3070
3055
Network
Interface
3065
Failover
Monitoring
Client Site
Network
3060
3030
Network
Interface
Health
Monitoring
3080
Passive
Storage Port
3020
Network
Interface
3025
Network
Interface
3035

Figure 29

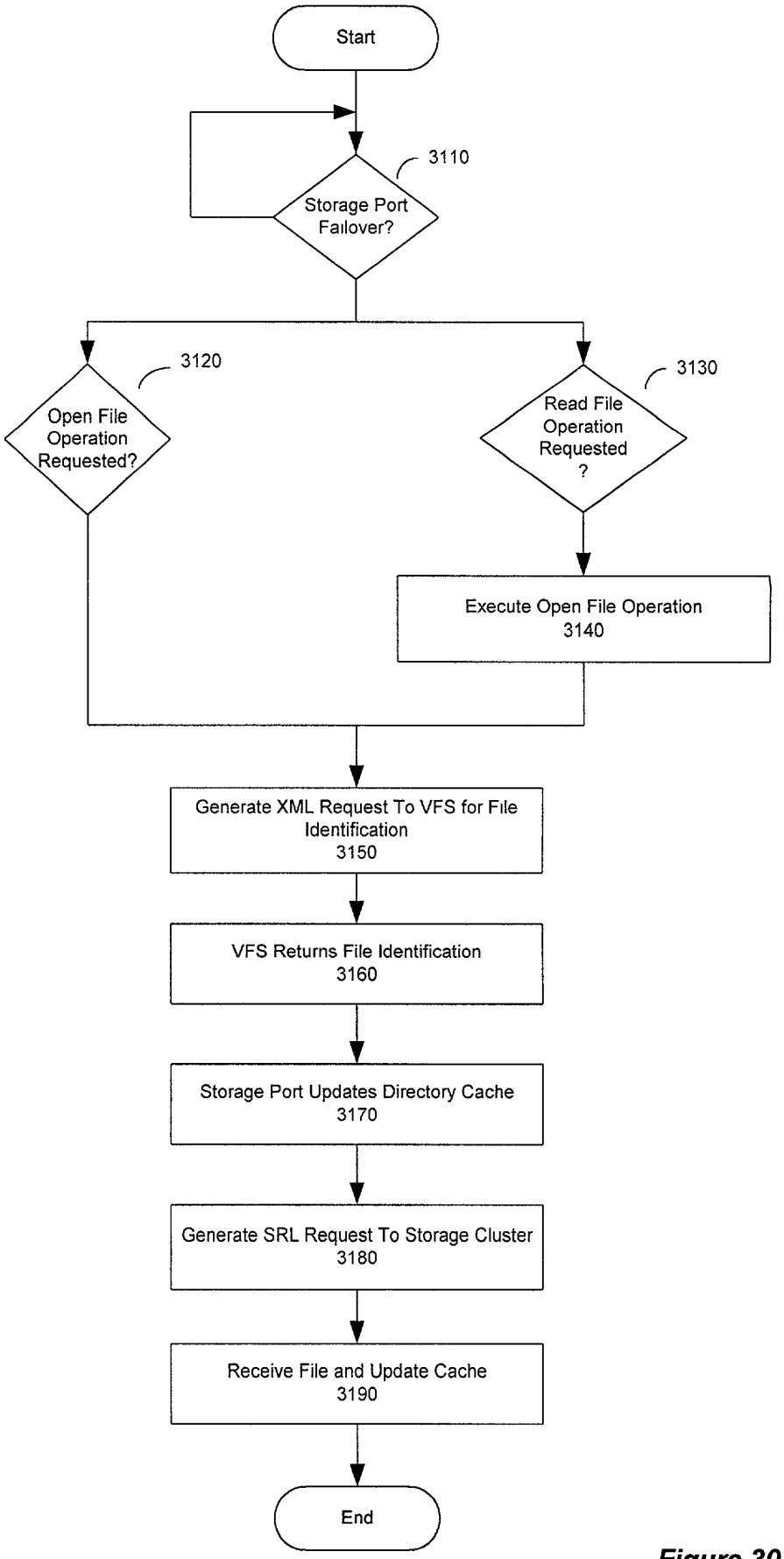

Start
3110
Storage Port Failover?
3120
Open File Operation Requested?
3130
Read File Operation Requested ?
Execute Open File Operation 3140
Generate XML Request To VFS for File Identification 3150
VFS Returns File Identification 3160
Storage Port Updates Directory Cache 3170
Generate SRL Request To Storage Cluster 3180
Receive File and Update Cache 3190
End

Figure 30

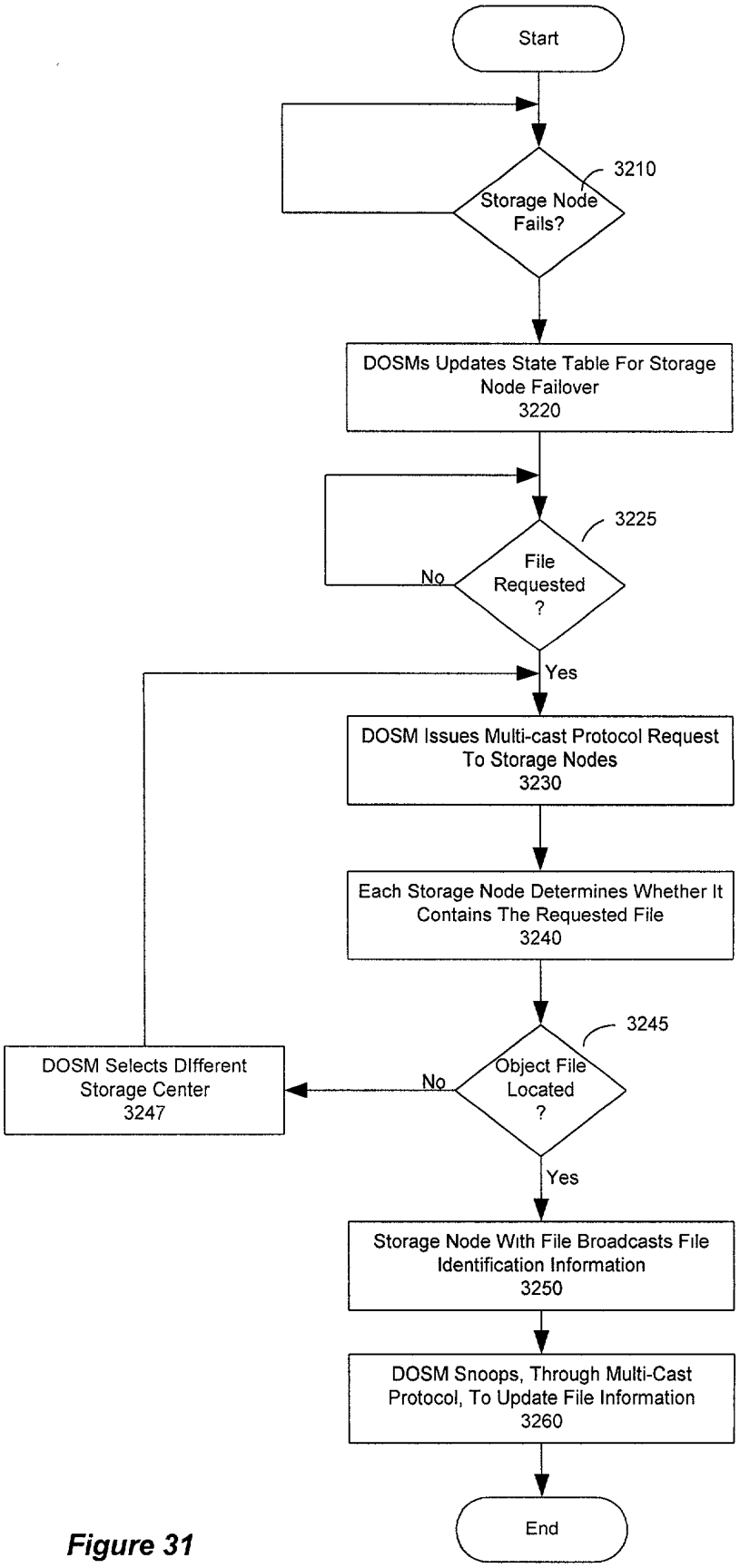

Start
3210
Storage Node Fails?
DOSMs Updates State Table For Storage Node Failover
3220
3225
File Requested ?
No
Yes
DOSM Issues Multi-cast Protocol Request To Storage Nodes
3230
Each Storage Node Determines Whether It Contains The Requested File
3240
3245
Object File Located ?
No
DOSM Selects DIfferent Storage Center
3247
Yes
Storage Node With File Broadcasts File Identification Information
3250
DOSM Snoops, Through Multi-Cast Protocol, To Update File Information
3260
End

Figure 31